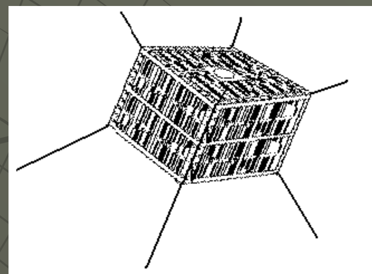
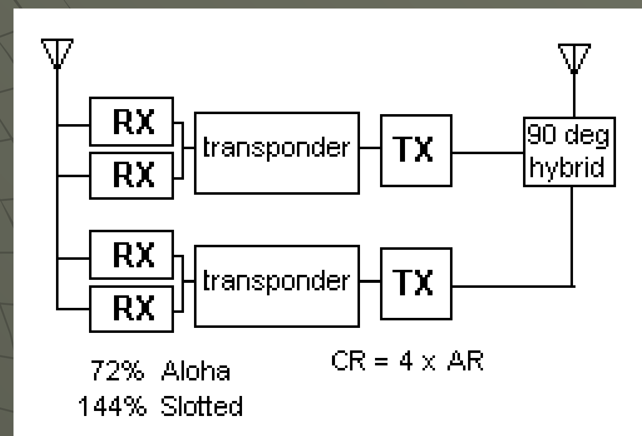
ParkinsonSAT

CDR Bruninga

USN (ret)



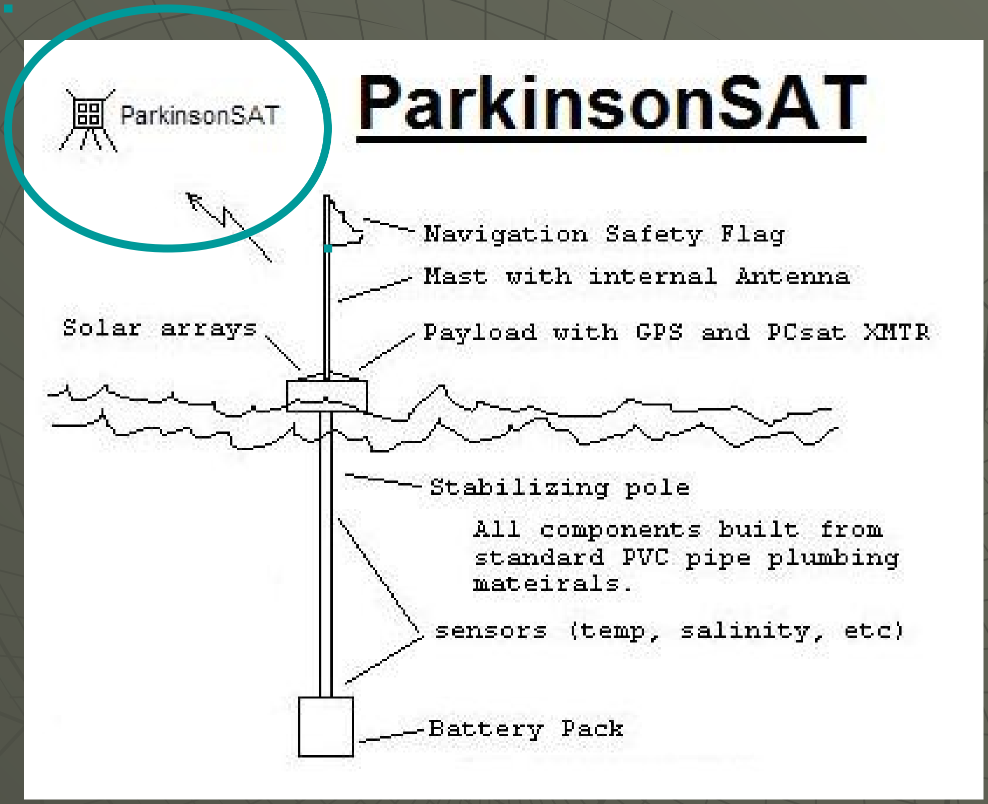
David Koeppel
Matt Lovick
James Paquette
Brian Piggrem
Jeff Robeson
Kyle Vandegriff



http://www.ew.usna.edu/~bruninga/buoy.html

Lovick

ParkinsonSAT



- $50k gift funds from Aerospace Corp.
- Environmental sensor satellite data transponder
- Satellite Launch Opportunities - TBD
- This semester, Preliminary Design options --> SRR

Original Project Proposal

- Communicate with simple environmental sensors – buoys – deployed in the Chesapeake Bay or the Gulf Stream.
- Relay buoy position/status and telemetry about 2 to 4 times a day back to the Naval Academy.
- Including Buoys elsewhere around the world as long as and internet linked ground station was in the footprint.
- Serve as a technology demonstrator for USNA auxiliary payloads such as basic satellite attitude control.

Proposed Mission

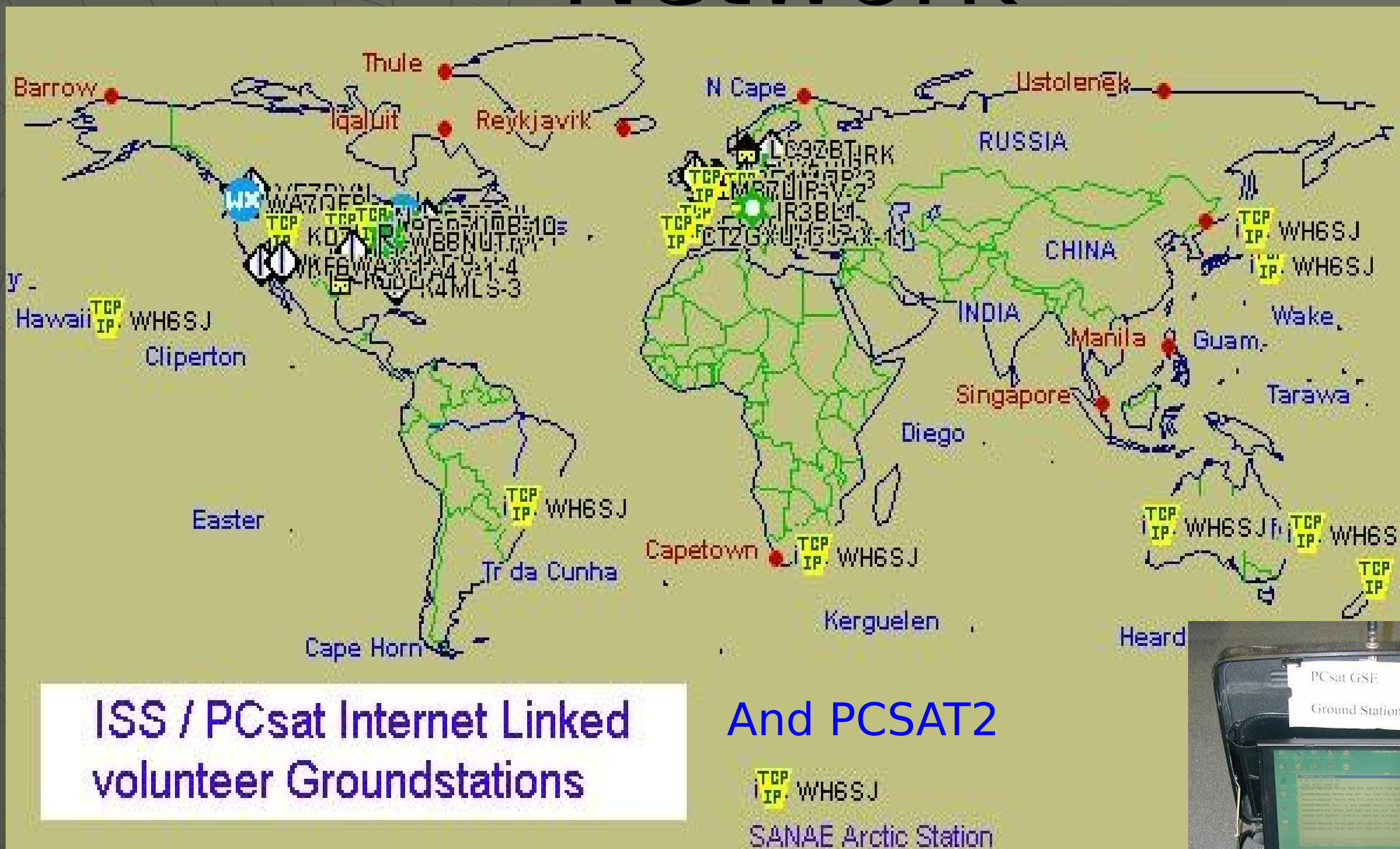
- Relay data from simple environmental sensors – buoys – in the Chesapeake Bay or oceans or onshore. Providing position/ status and telemetry about 2 to 4 times a day to the Internet.
- Including Buoys elsewhere around the world as long as Internet linked ground stations are in the footprint.
- Establish this channel/system as a global resource for other such experiments in the Amateur Satellite Service. Inspire other schools and universities to participate with additional low cost satellite transponders and buoy and sensor systems.
- Serve as a technology demonstrator for various spacecraft subsystems including basic attitude control, follow-ons to PCSAT experiments and other student projects such as the MIDN sensor.
- Support an Ocean Data Telemetry Microsat Link (ODTML) UHF transponder for DOD.

Low Cost Buoy System

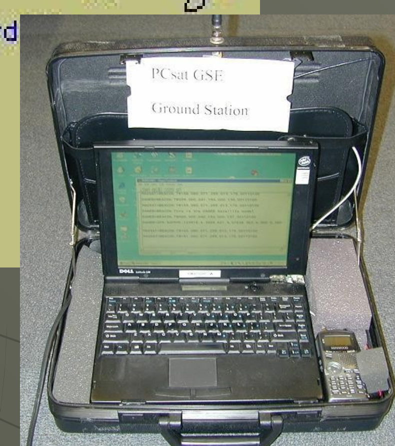
USNA Buoy

- Low Cost ~ $800
- Standard plumbing hardware
- Off-the-shelf radios/modems
- Operates under FCC rules for Amateur Satellite Service

Global Ground Station Network



And PCSAT2



Needs only a Radio, Modem, PC and Internet

Piggrem

Micro Dosimeter (MIDN) Requirements

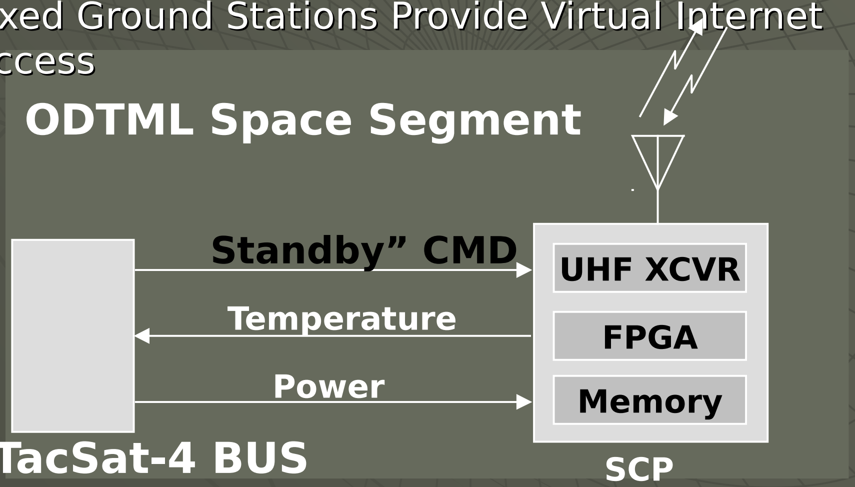
Auxiliary USNA Aerospace Student Project Payload

- Size – 2.5” x 2.5” x 6”
- Weight – .215 kg
- Power – 1W (@ 5v)

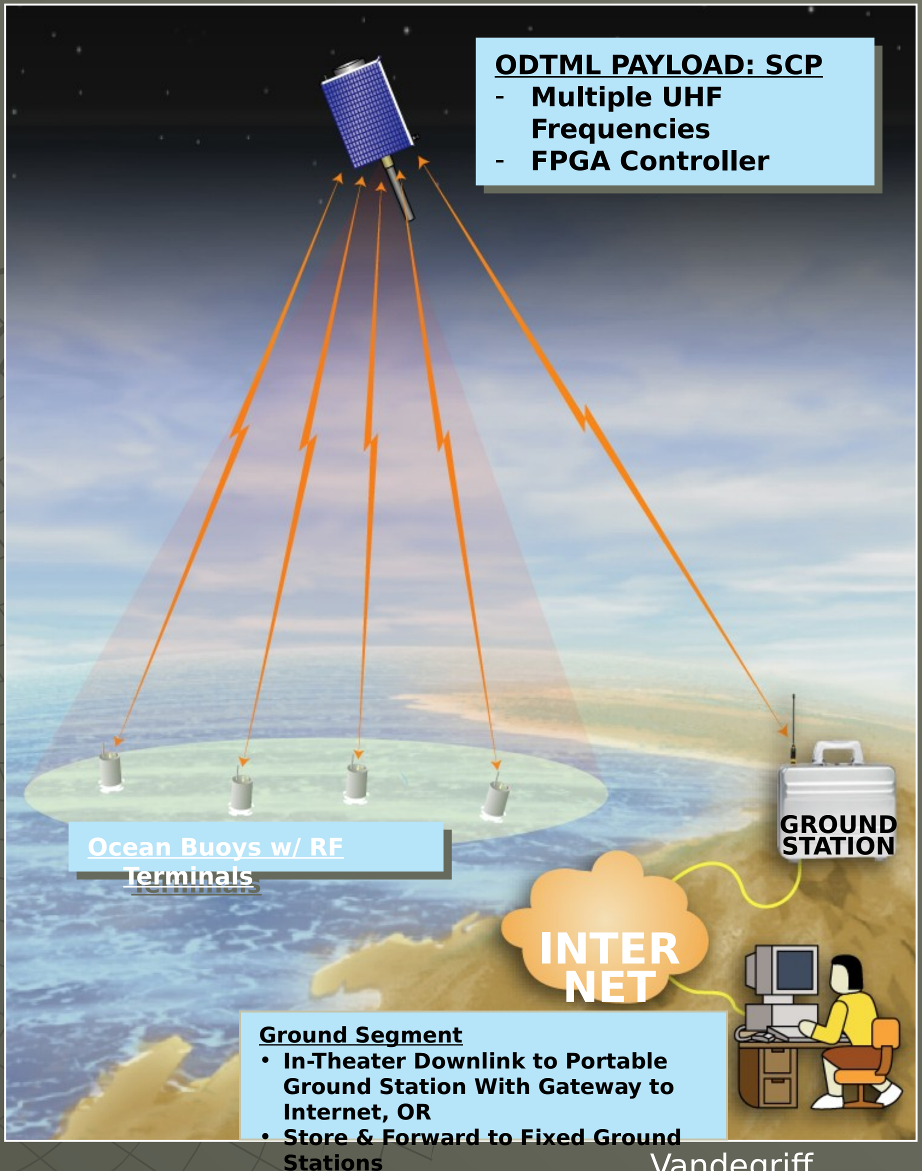
Measures radiation dosage in human cell sized detectors

Ocean Data Telemetry Microsat Link, ODTML

- CONOPS: "Internet-Like" Services on Global Basis to Support Ocean Platform Monitoring (e.g., Free-Floating Buoys)
- SPACE SEGMENT:
  - Hosted Aboard TacSat-3 and TacSat-4
  - Autonomous "Router in the Sky" Allows User Commanding and Telemetry Receipt (Peer-to-Peer and Store/Forward)
  - Compatible With Service ARGOS; >50,000 Bits/Day per Buoy; <0.1 Joule/Bit With Global Access and Position Determination
  - UHF Uplink/Downlink With GMSK Modulation
- GROUND SEGMENT: Low-Cost Portable and Fixed Ground Stations Provide Virtual Internet Access



Concept of Operations



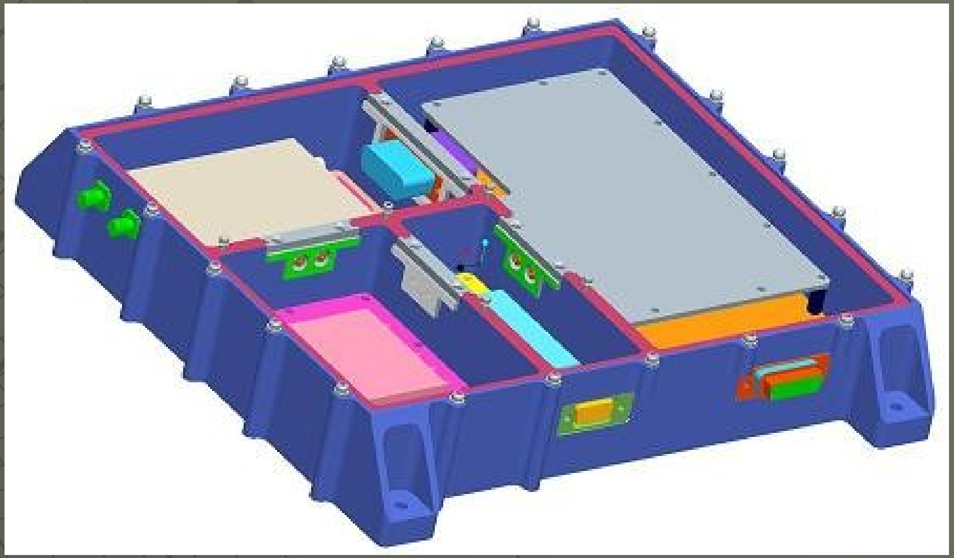
Vandegriff

ONR ODTML

Size, Weight and Power

- Size – 10” X 10” X 1.8”
- Weight – 3.7 kg
- Power

Peak (Watts)	40
Nominal (Watts)	9.5
Average (Watts)	12.5



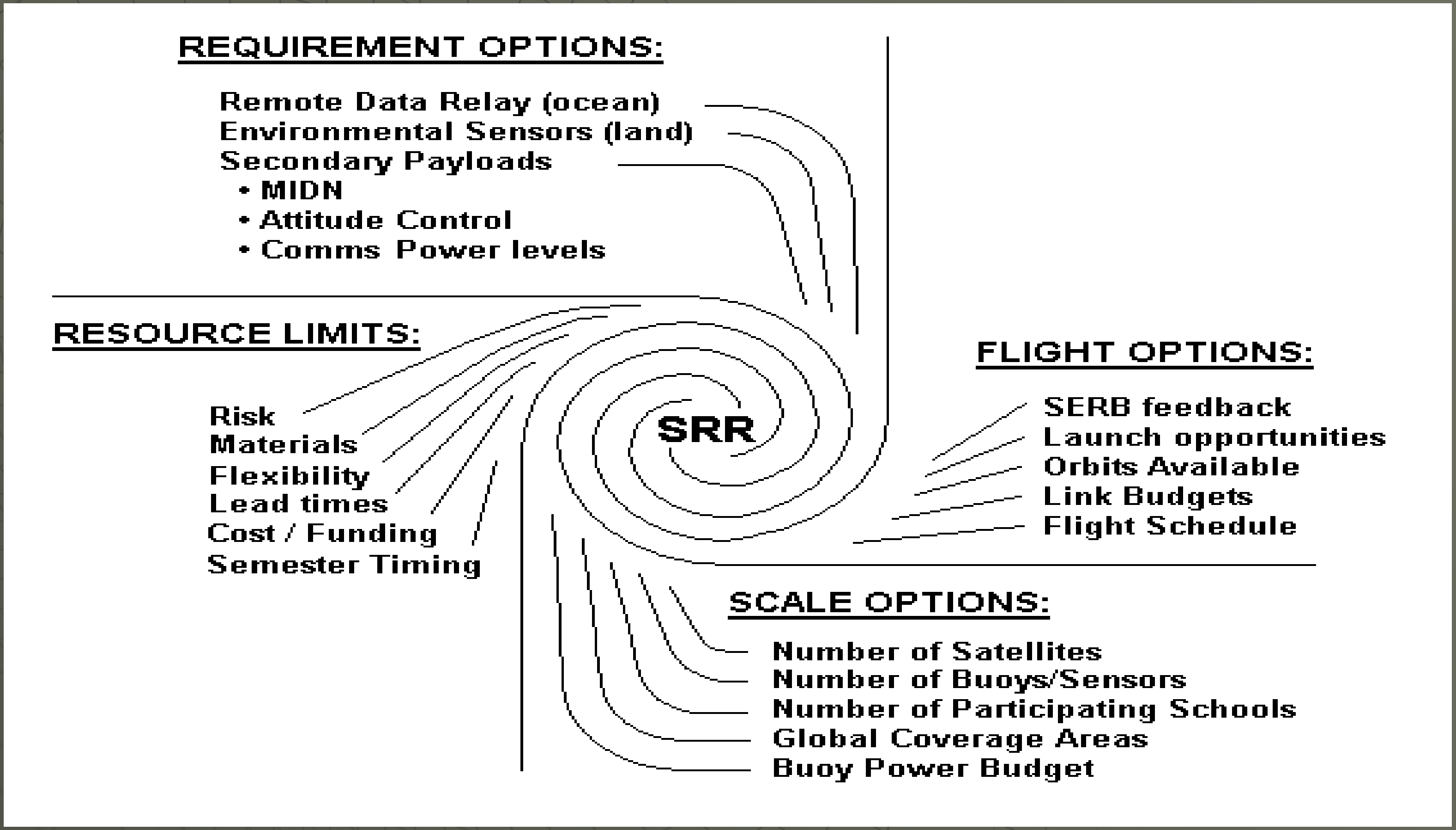
For a 28v bus regulated down to 5v.

For our 8v bus and with some conservation, maybe 10W average.

Project Variables

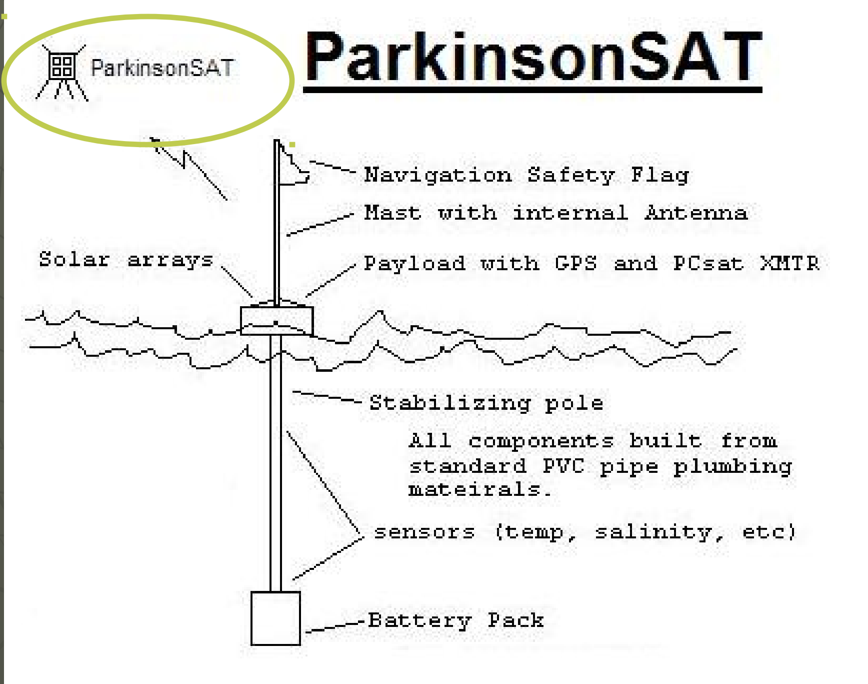
- Requirement Options?
- Launch Options?
- Scale options?
- Resource Limitations?

ParkinsonSAT
Spiral Design Approach



Lovick

ParkinsonSAT
Link Budget is Known



- Buoy to Satellite (VHF)
  - Pr (90° el) = -101 dBm
  - Pr (0° el) = -117 dBm
- Satellite to Buoy (UHF)
  - Pr (90° el) = -110 dBm
  - Pr (20° el) = -117 dBm

  Satellite to Buoy (VHF) aux TX
  - Pr (90° el) = -101 dBm
  - Pr (0° el) = -117 dBm
- Satellite to Groundstation (UHF)
  - Pr (90° el) = -110 dBm
  - Pr (20° el) = -117 dBm
- Satellite to Trackingstation (UHF) +8 dB
  - Pr (90° el) = -102 dBm
  - Pr (0° el) = -117 dBm

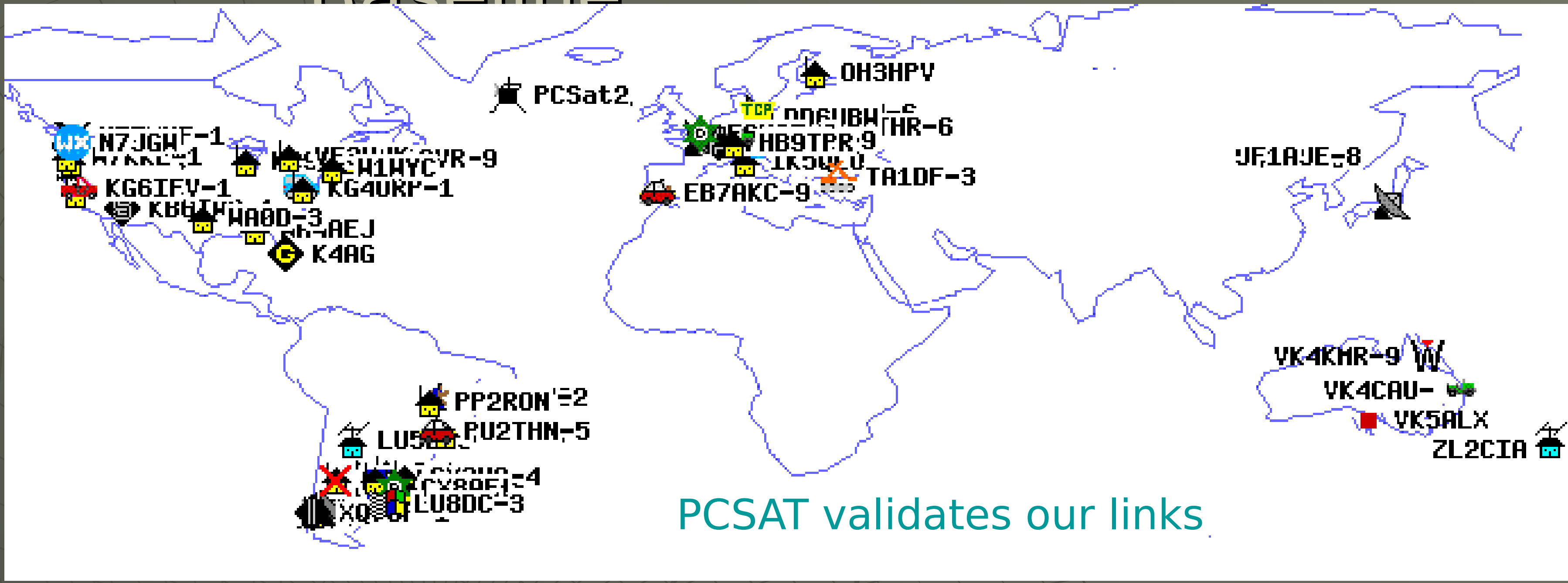
Challenge: All using OMNI antennas

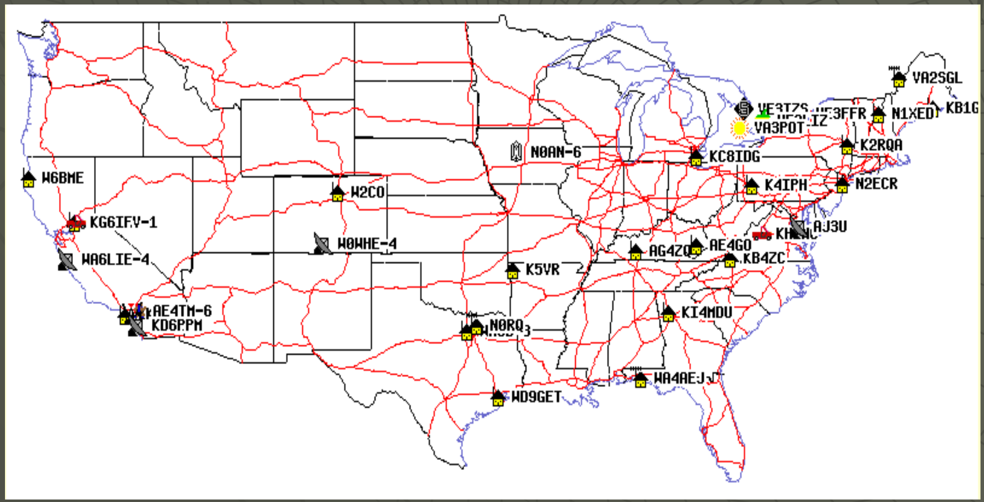
RX sensitivity -117 dBm

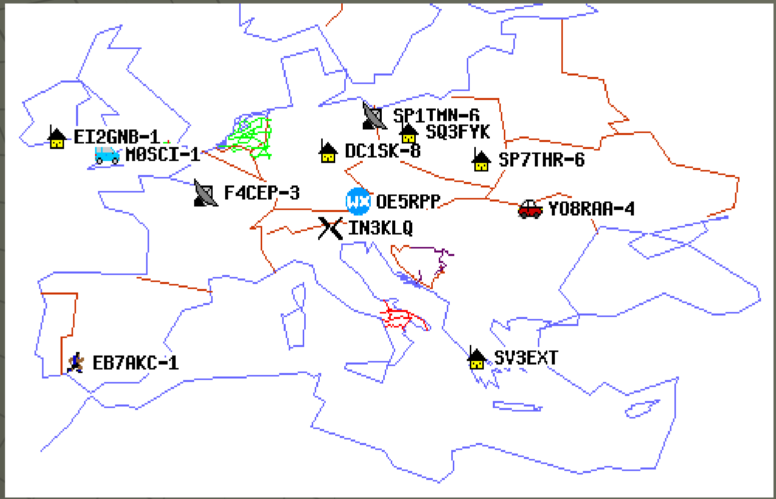
Vandegriff

Sensor Buoy Baseline

PCSAT2 User Plot 18 Apr 06







Vandegriff

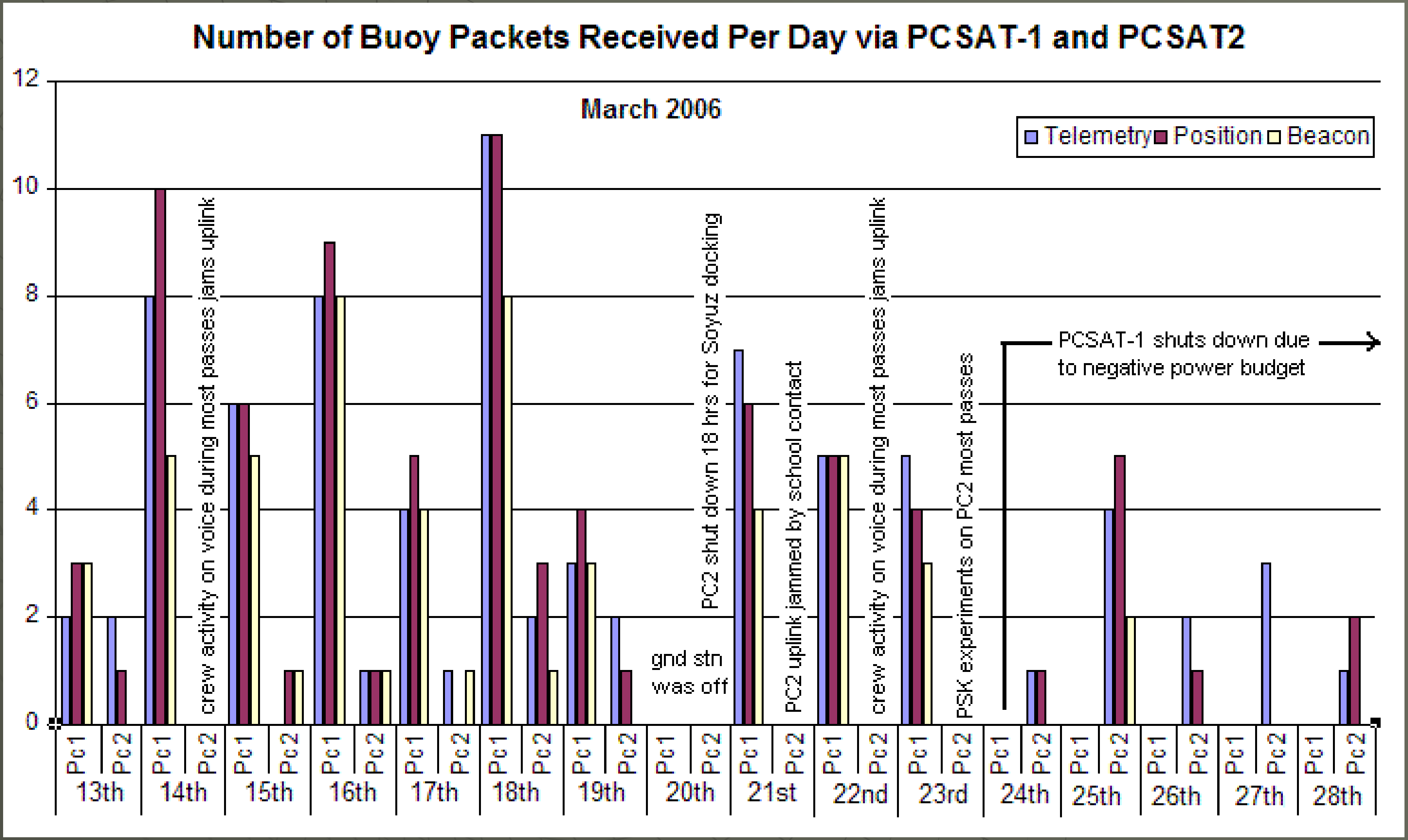
Sensor Buoy Baseline

GOES data collection platform container

Our RF prototype on Roof

Paquette, Robeson

Sensor Buoy Baseline



Paquette

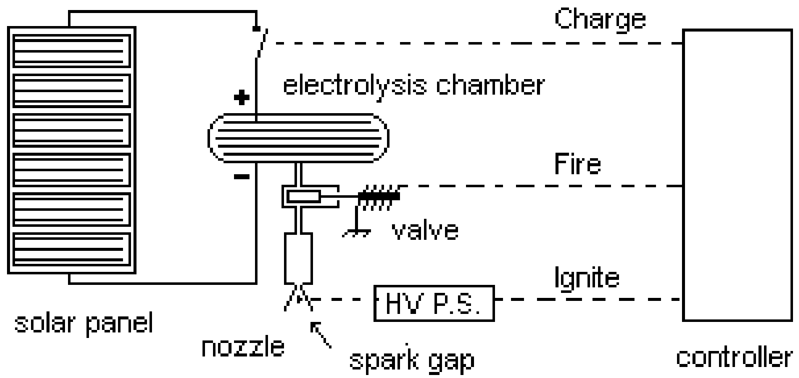
Launch Opportunities

- Free Flyer (comms orbit) - Desired
- Attached Payload – OK
- Space Shuttle – too low, no life…
  - Available Launcher – 5” picosat (minimum system)
  - Requires a Propulsion system (H_2O_2 man-safe)

H_2/O_2 Man Safe Propulsion

The only practical way to get a student built propulsion system on board Space Shuttle. Inherently SAFE.

ParkinsonSAT H_2/O_2 Micro-Thruster



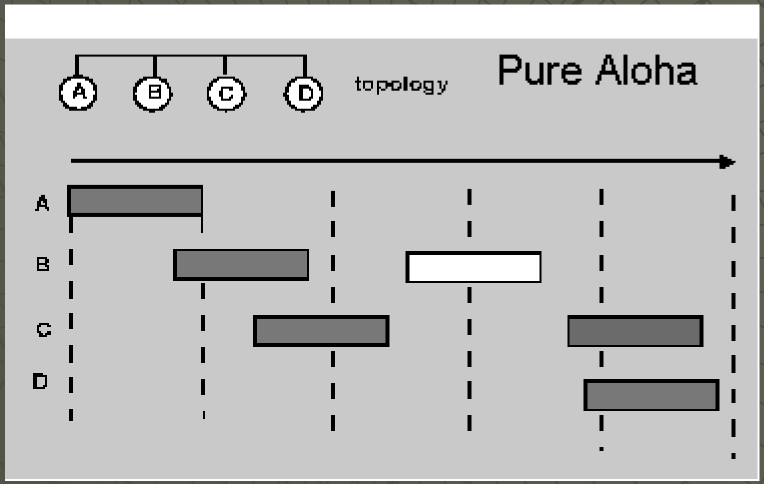
Project:

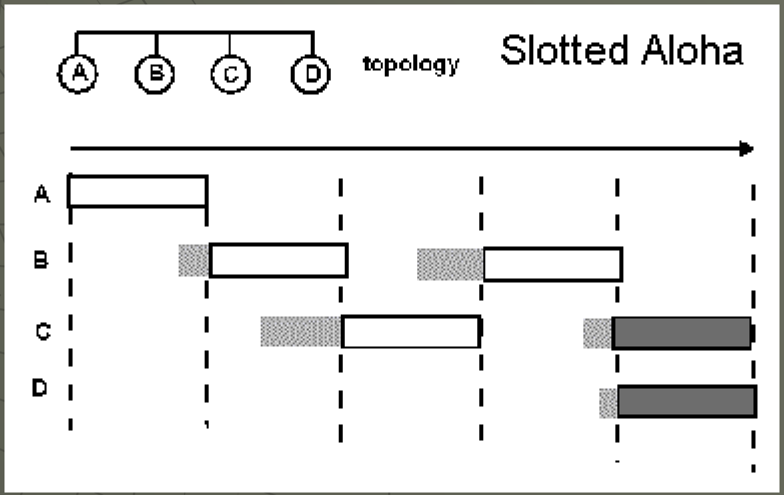
Determine spacecraft mass then delta-V requirement
Electrolysis requirements, rates, power required
Valve avilability and drive requirements
Water/gas separation mechanism (gortex?)
Design-Build-Test engineering model
Final conceptual design

Possible Future Project…

Mission Scale - Channel Capacity

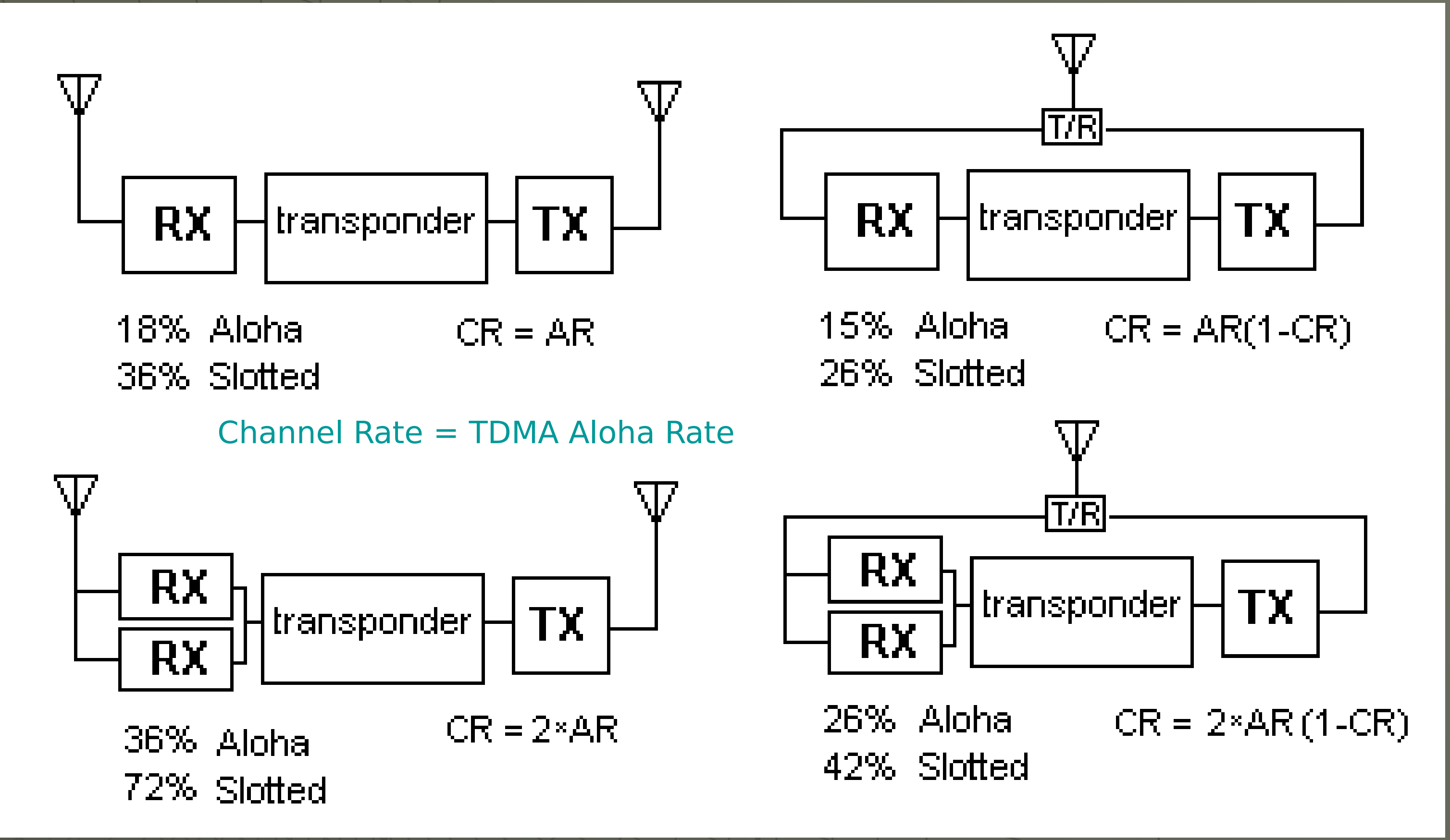
- Time Division Multiple Access (TDMA)
  - Pure ALOHA 18% channel capacity
  - CSMA ALOHA 36% channel capacity (not via sat)
  - Slotted ALOHA 36% (uses GPS timing)





Lovick

Mission Scale - Receivers

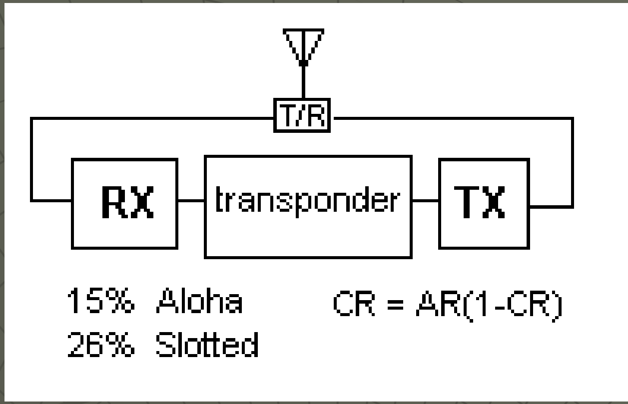


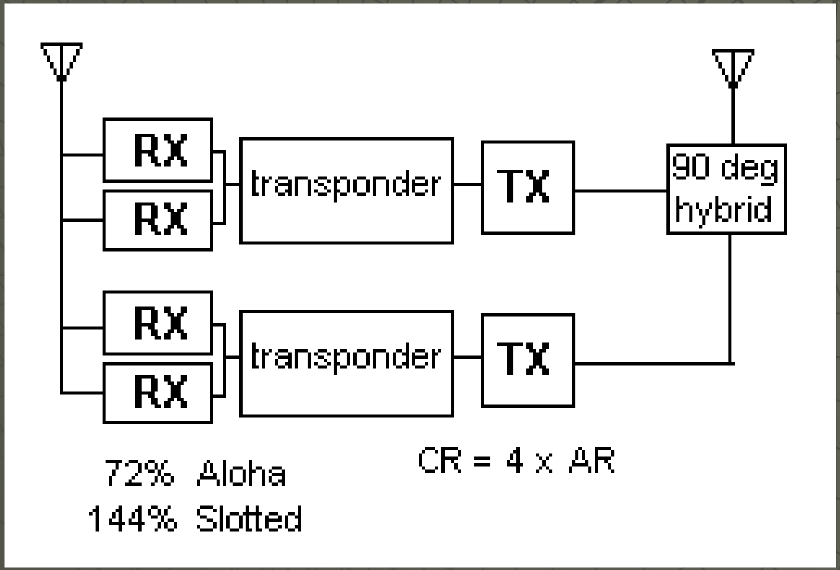
Full-duplex, Crossband

Simplex / In-band

Lovick

Mission Scale – Options





Minimum System:

- 32 Buoys/footprint
- 5” Picosat

Maximum system:

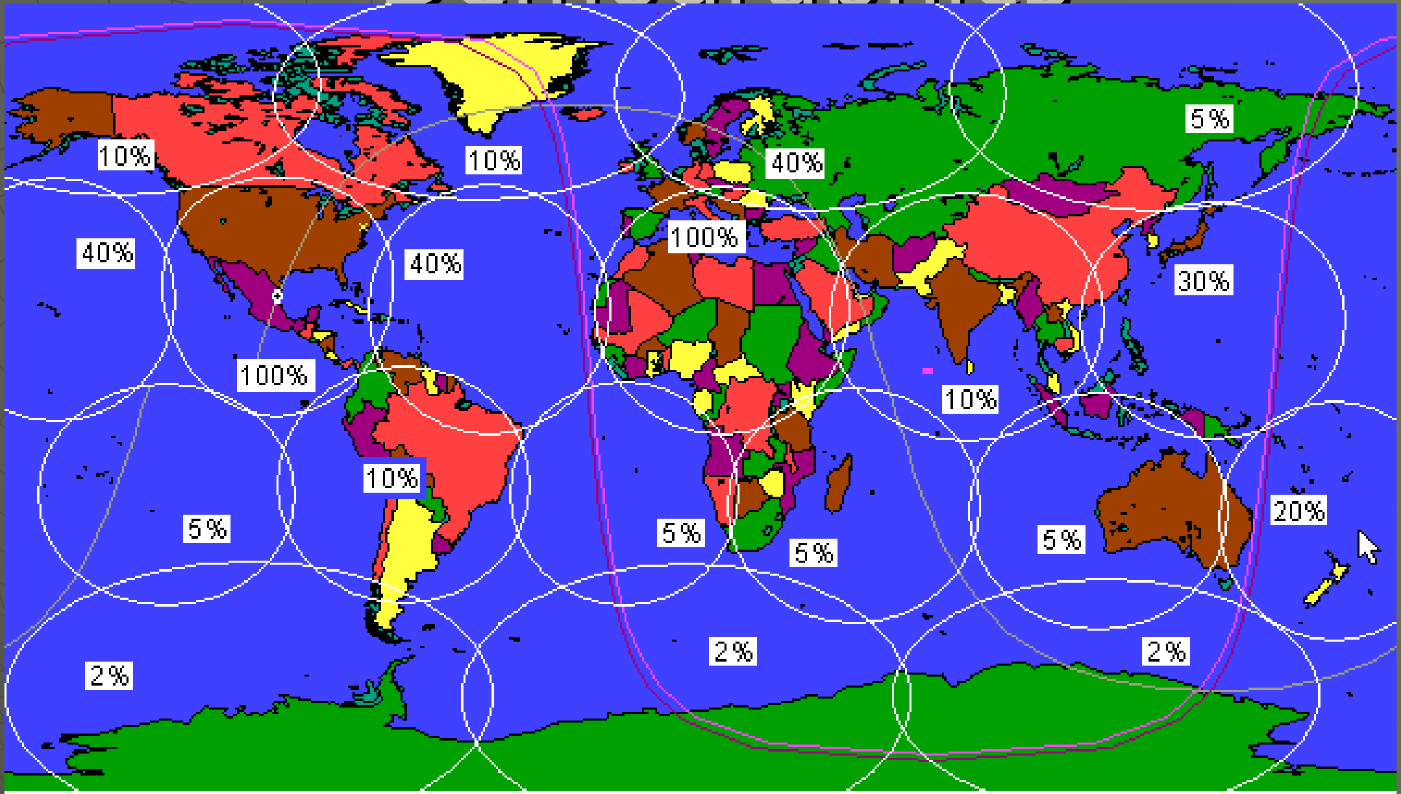
- 144 Buoys/footprint
- Dual redundant
- 12” Microsat

AT 1200 BAUD

(2 x if 2 RX at 9600)

Lovick

Mission Scale – Buoy Demographics



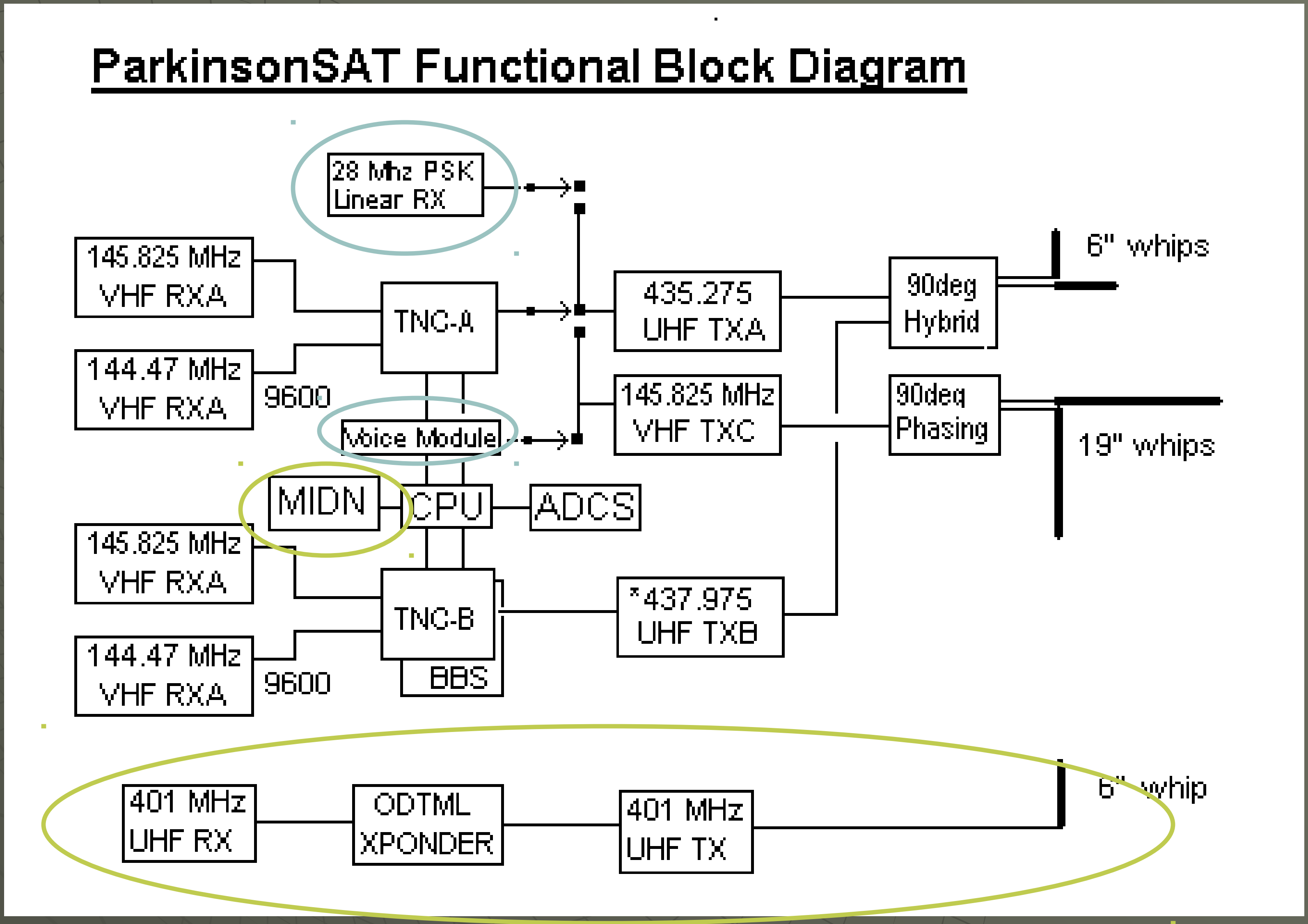
Global coverage for 3000 km radius footprints. One footprint is about 5% of area. .
Overall global average dutycycle is about 20%.

Theoretical capacity: 2880
144/5%

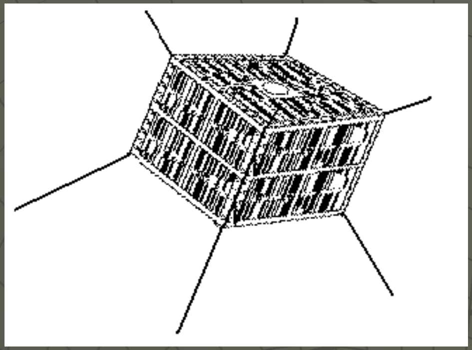
Expected capacity: 720
144/20%

Lovick

Architecture



Small Satellite Structural Options



- Primary factor is solar panel sizing
- Next is Antenna requirements
- Separation System
- Attitude Control requirements

Koeppel

Solar Panel Options

- Available Area
- Efficiency
- Cost
- Attitude
- Bus Voltage

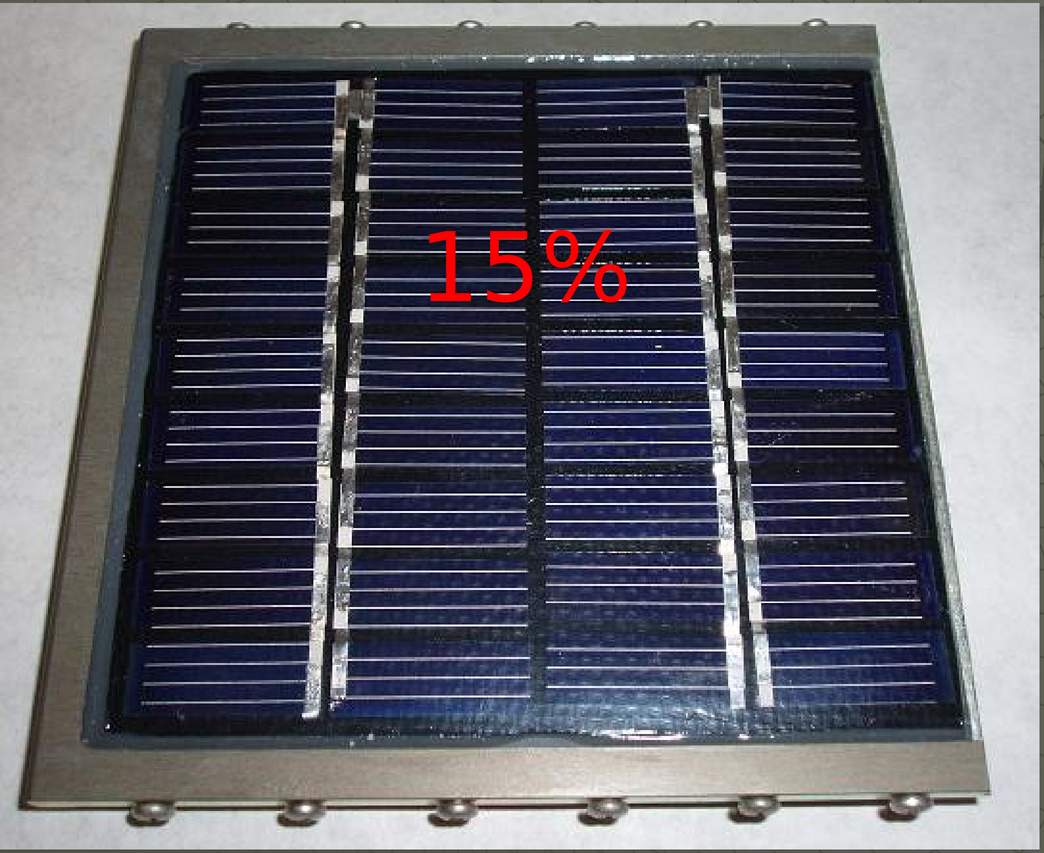
Solar Cell Options

$500 / Watt

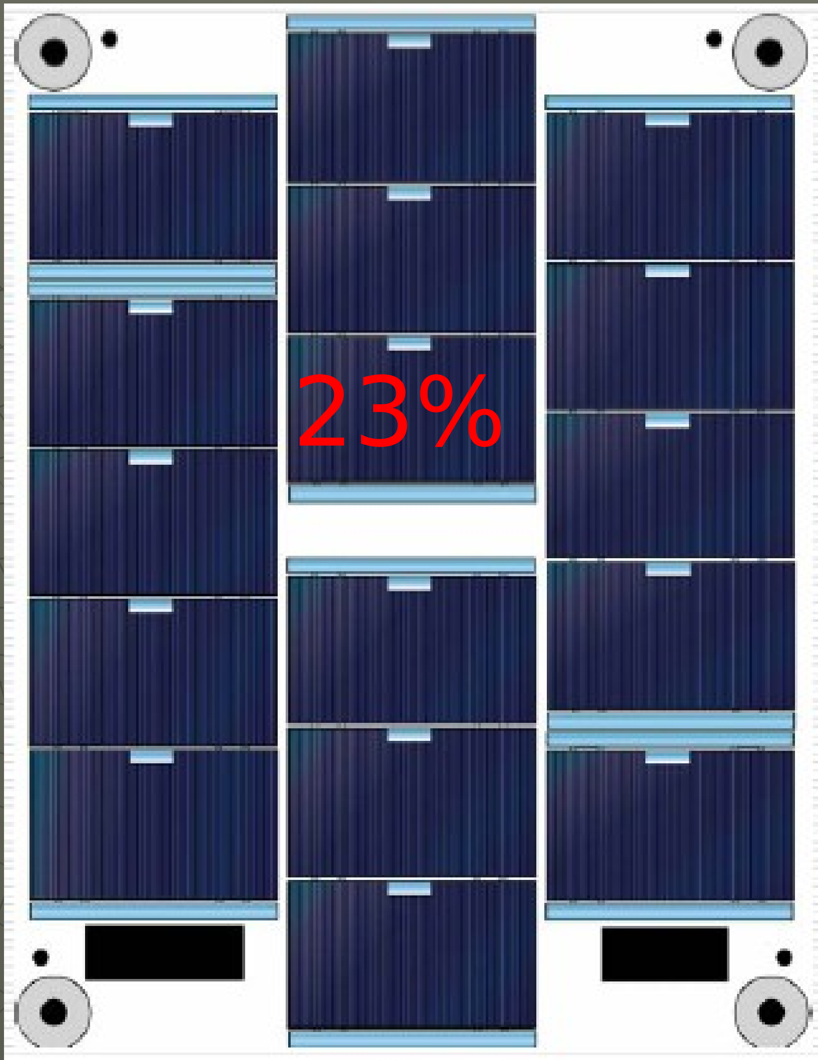
EMCOR University Cells

PCsat Panel

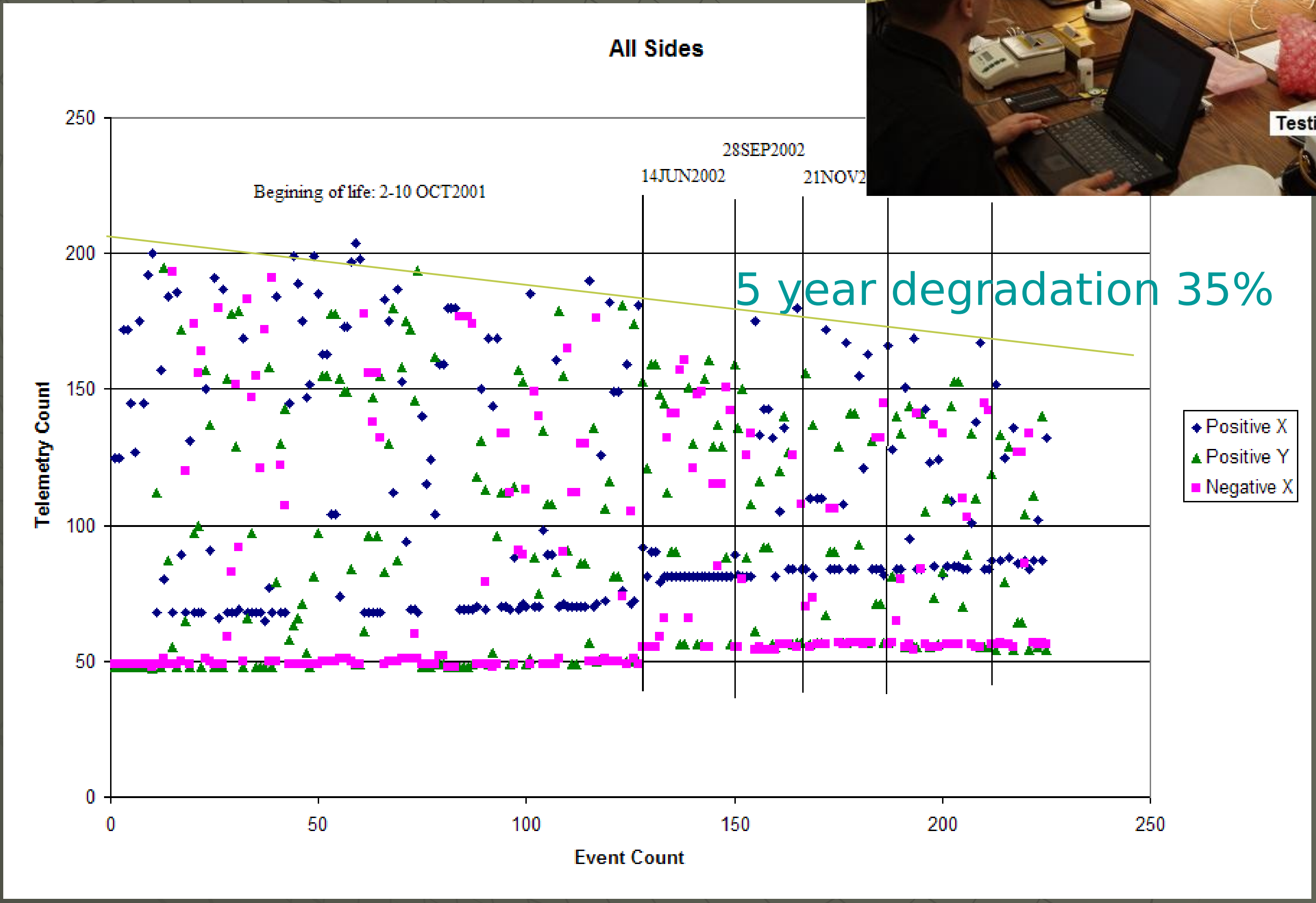
$20 / Watt



Koeppel



PCSat Solar Panel Data

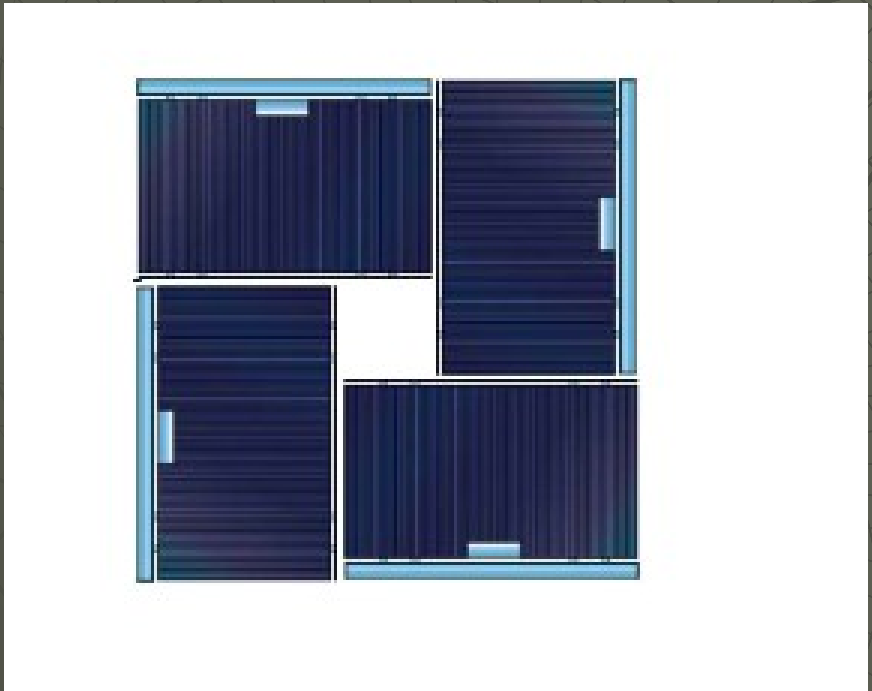


5 year degradation 35%

Koeppel

Emcor University Cell Options

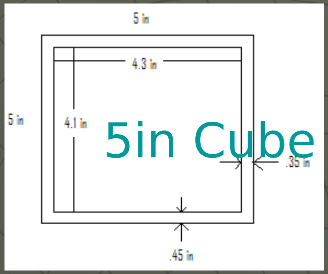
4 cell 8V set

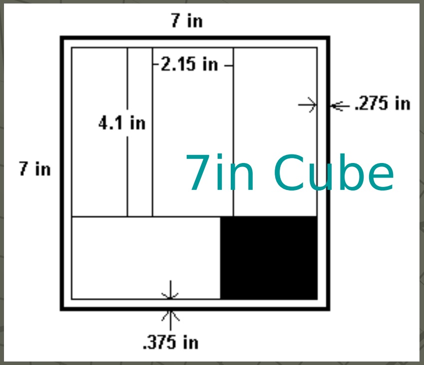


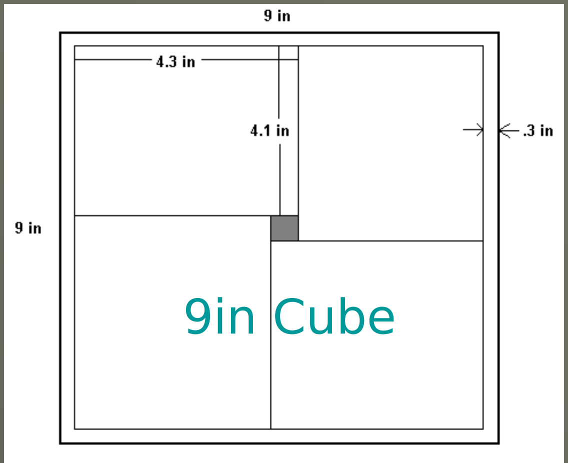
6 cell 12v set

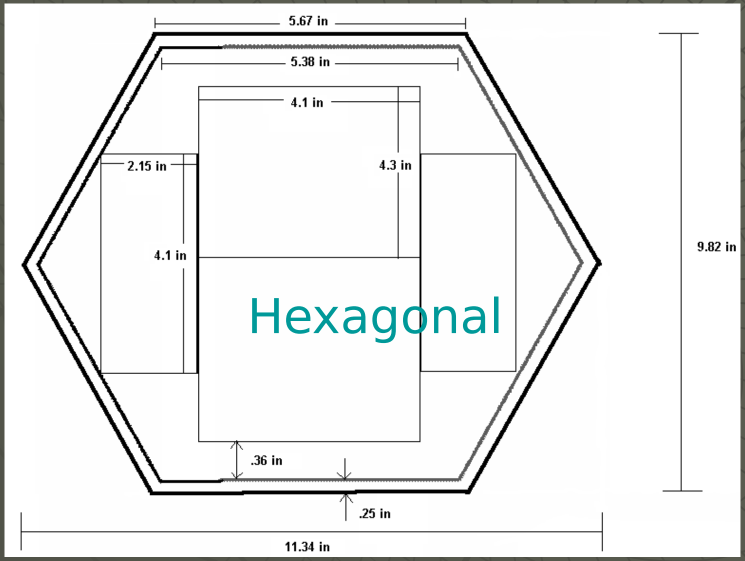
ParkinsonSAT

Shape / size Constraints

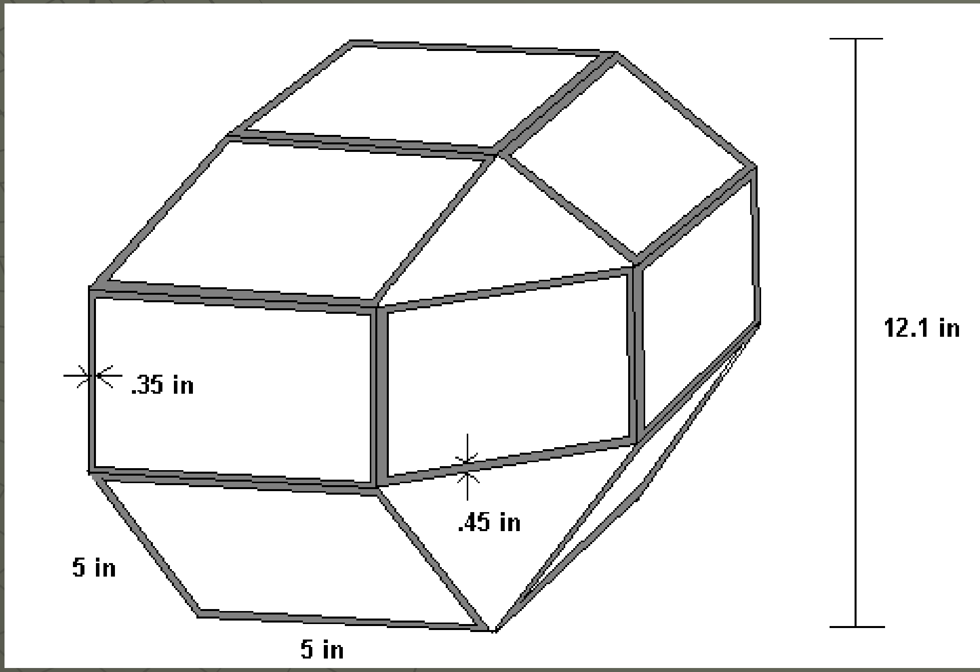








Rhombicuboctahedron



ParkinsonSAT

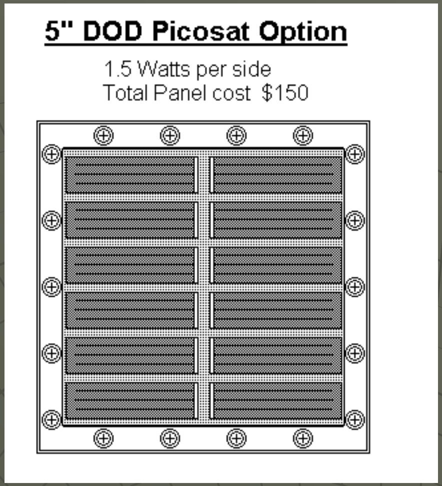
Shape / Size Constraints

Shape	Solar Panels	Max Power (W)	Min Power (W)	Volume (in^3)	Surface Area (in^2)
5in Cube	**6**	3.49	2.03	**125**	**150**
7in Cube	12	7.04	4.06	343	294
9in Cube	**24**	**14.1**	8.13	729	486
Hexagonal	9	6.10	**1.67**	208.8	252
Octagonal	12	8.13	2.45	273.5	314
Rombicub octahedron	18	9.15	7.78	**1061**	**518**

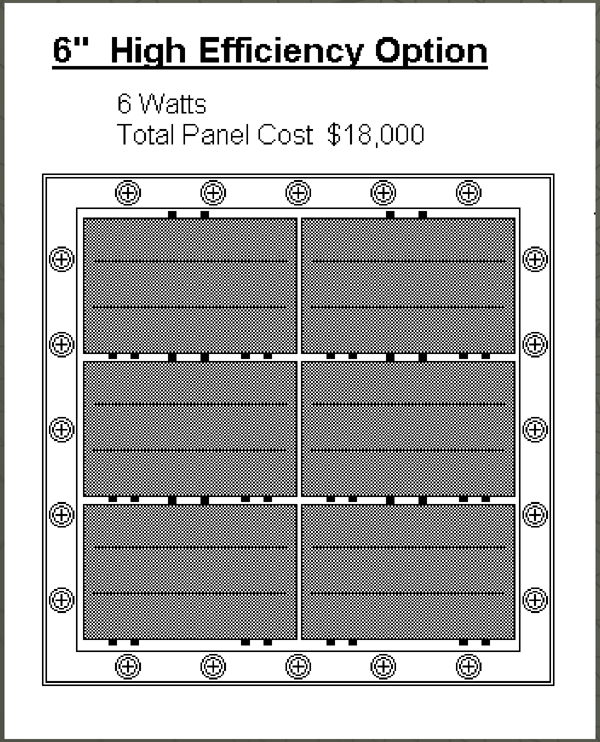
Vandegriff

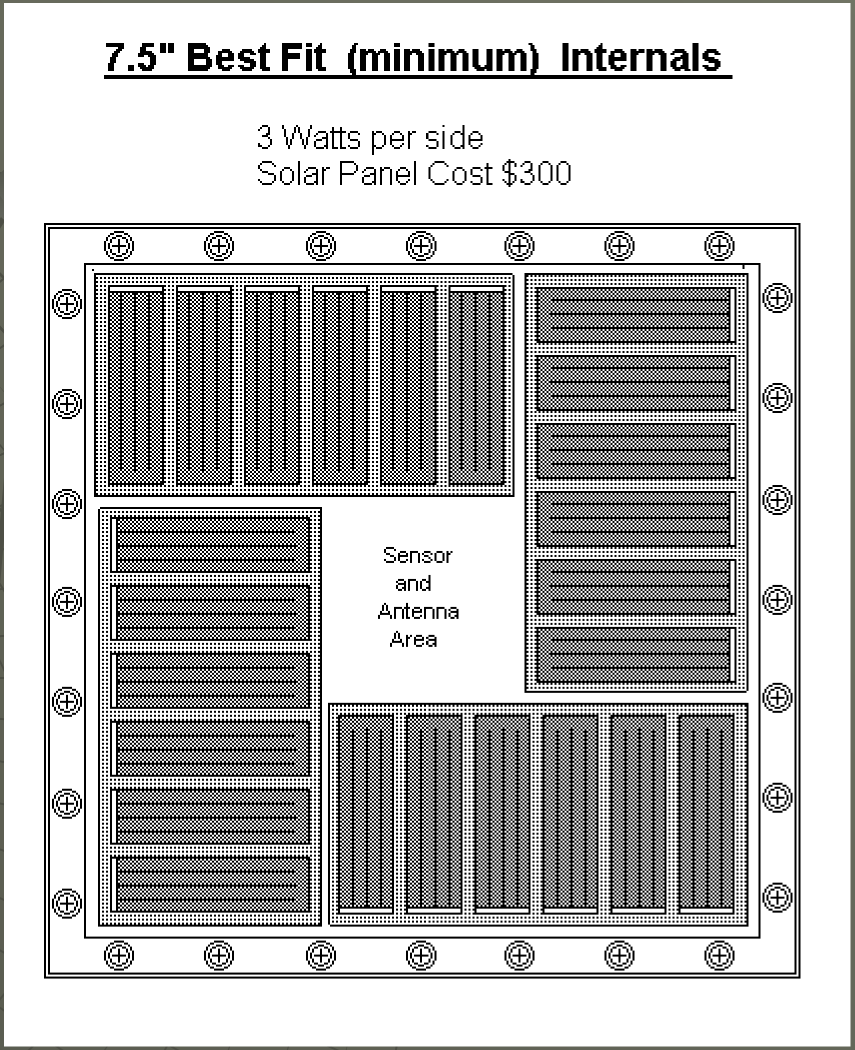
ParkinsonSAT

Straw-man Options



Discrete sizes





Vandegriff

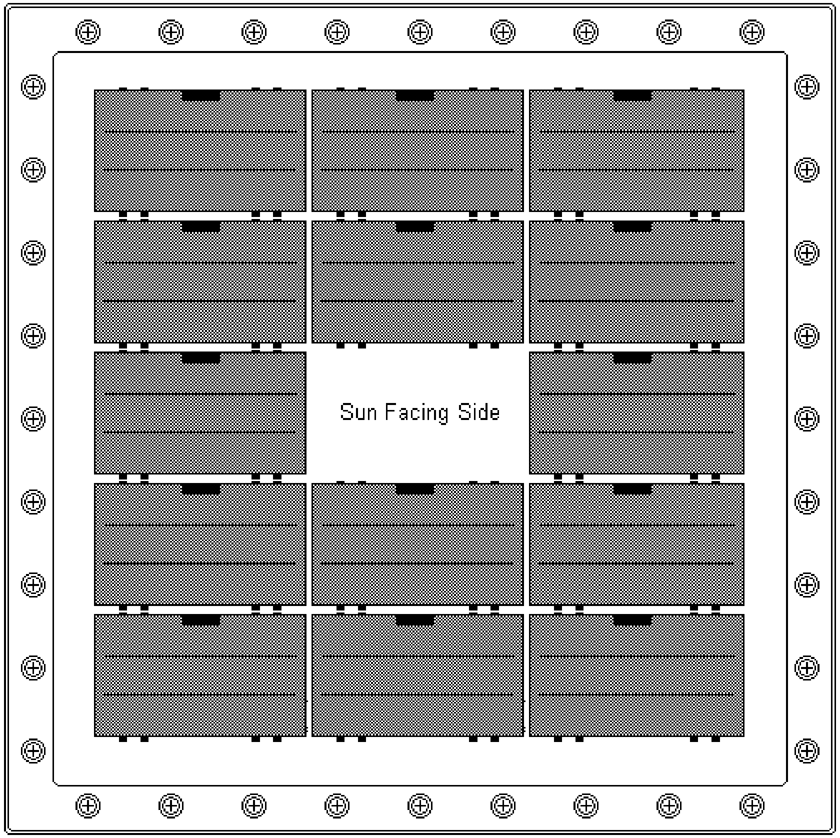
ParkinsonSAT

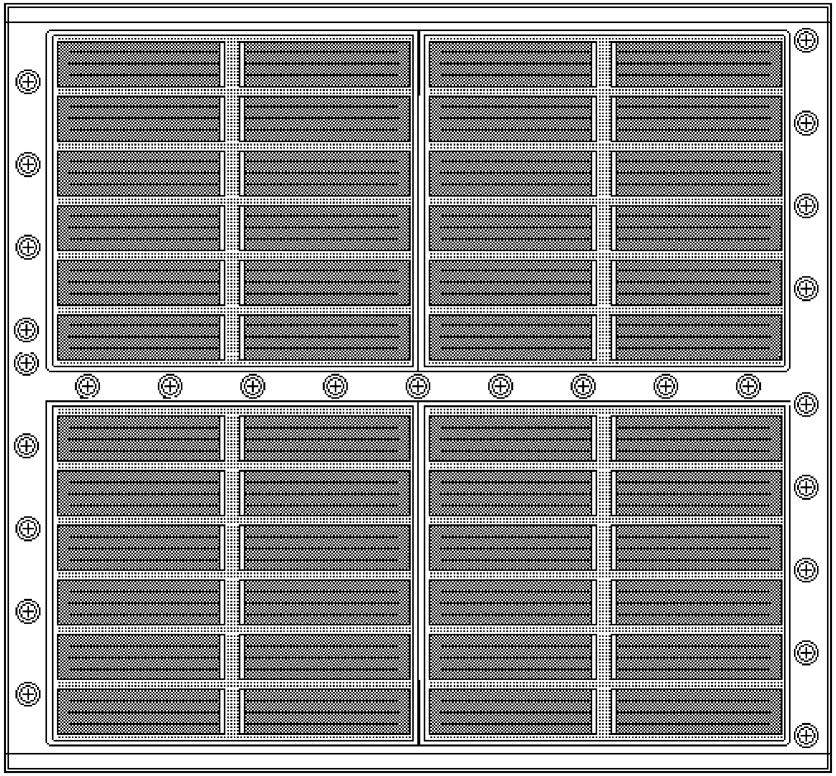
Sun Pointing

Straw-man Designs

10" Option with 12 volt Bus

10 Watts $5000 X 6 = $30,000





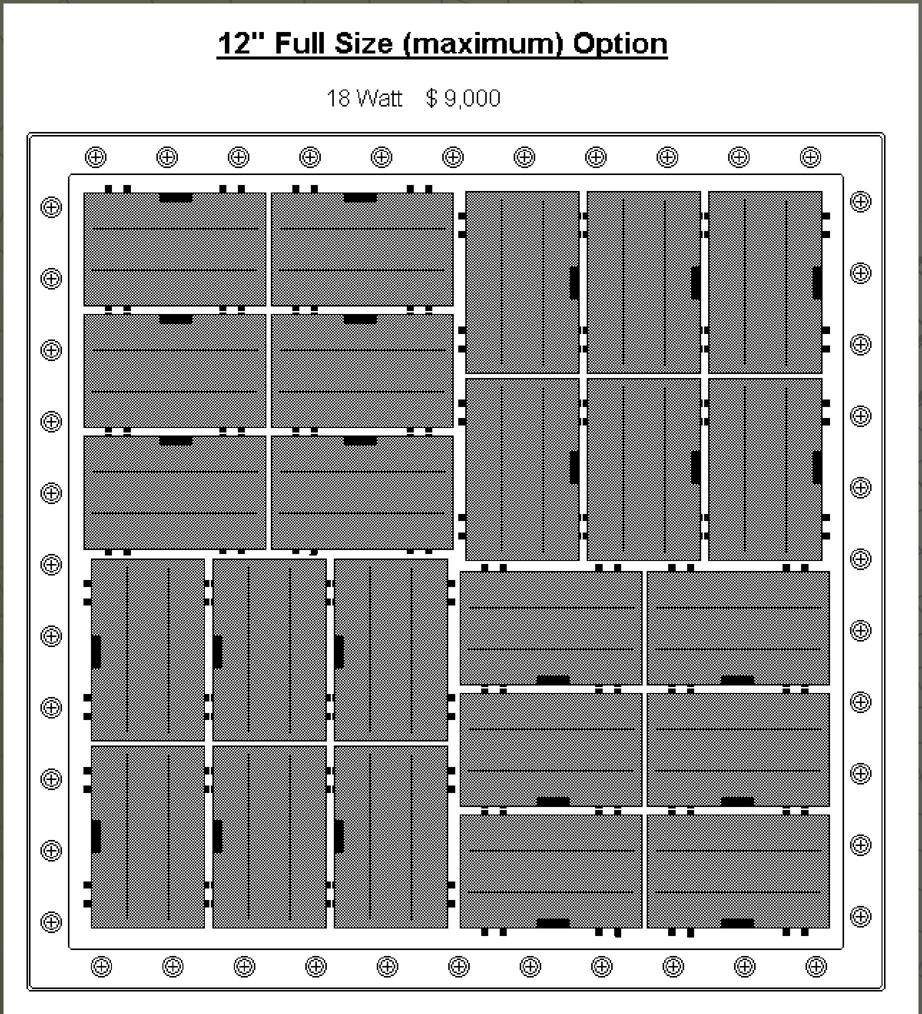
Side View 6W $100

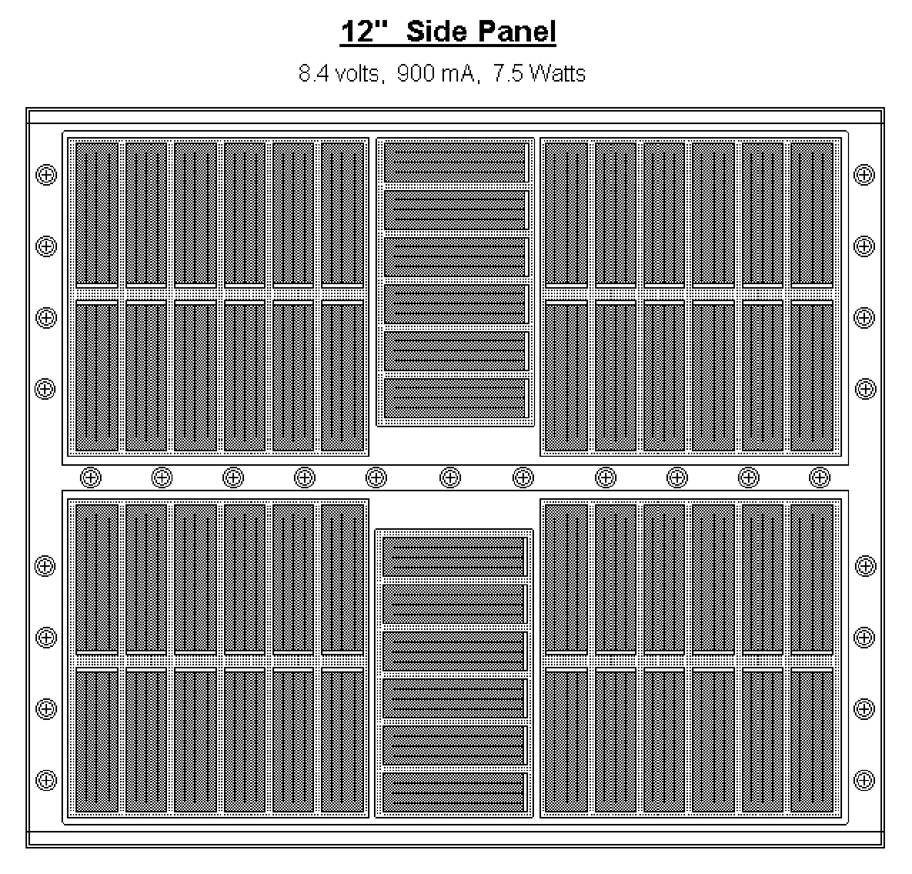
Vandegriff

ParkinsonSAT

Sun Pointing

Full System Design

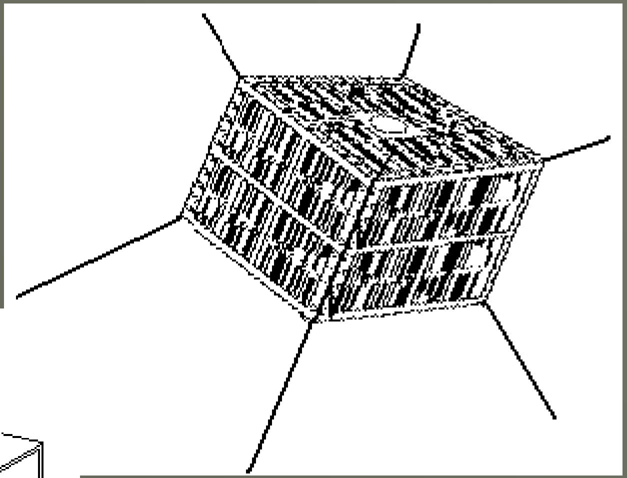


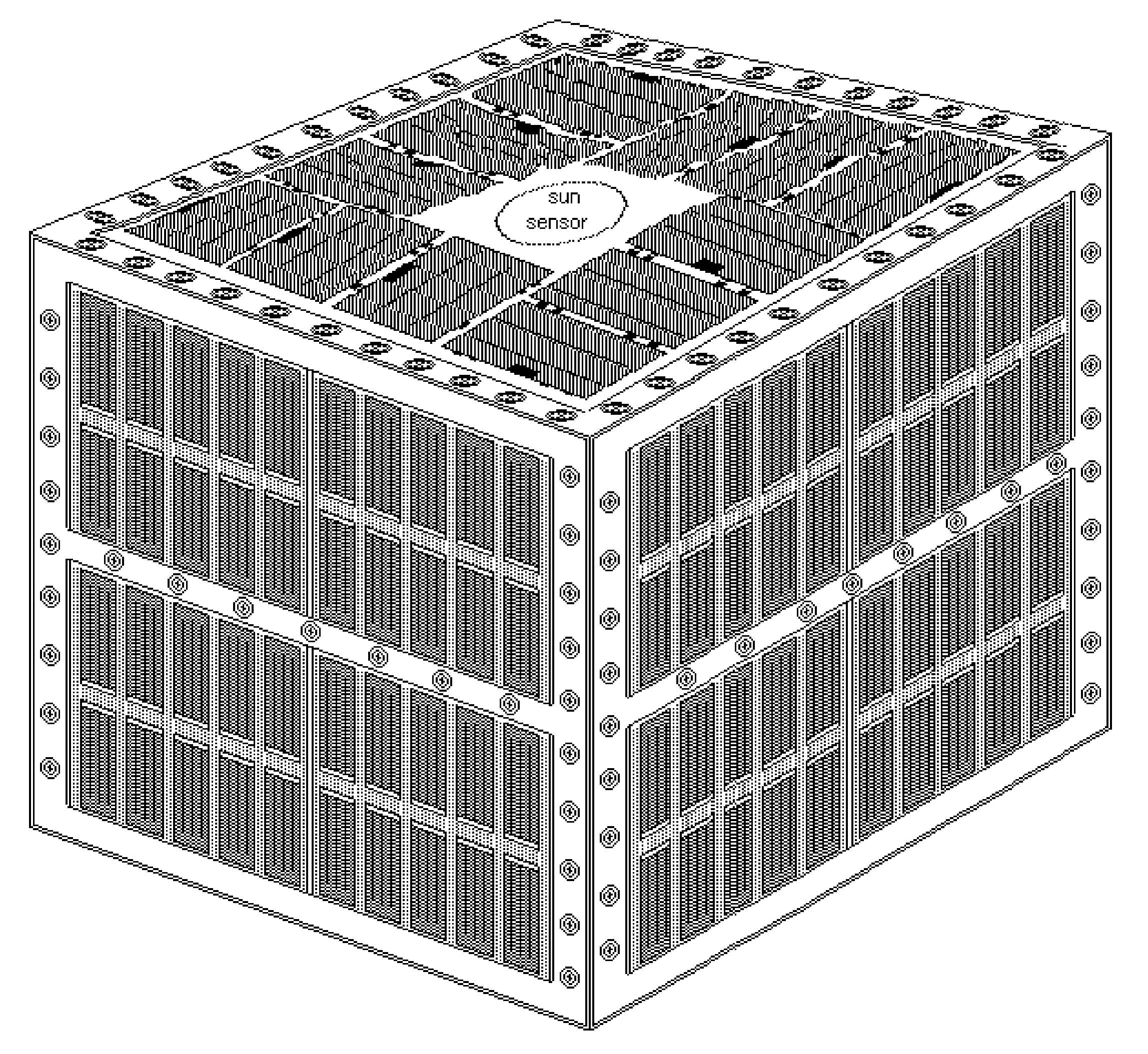


Vandegriff

ParkinsonSAT

Sun Pointing Design



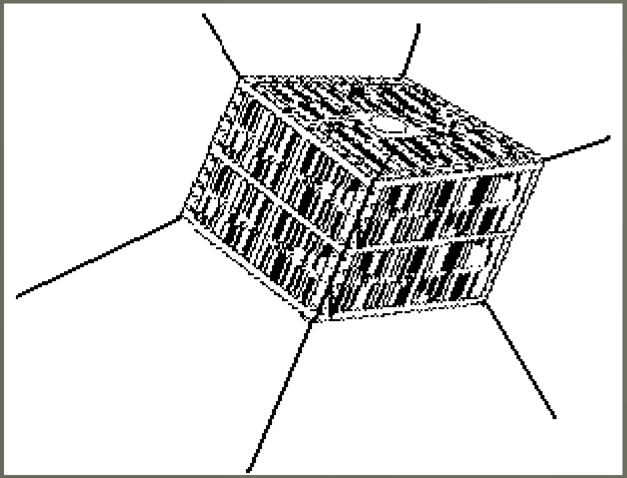


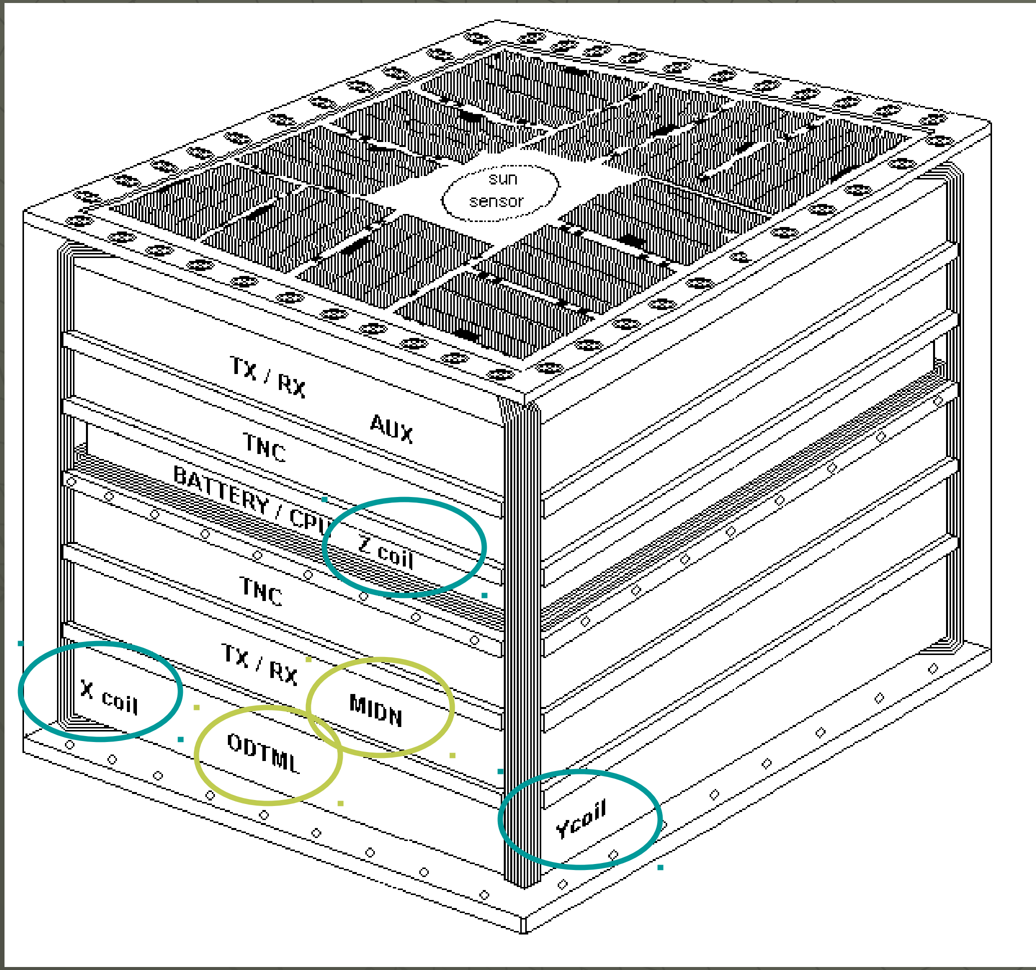
- Full capacity mission transponders
- ODTML Transponder
- MIDN Payload
- ADCS advantage

Vandegriff

ParkinsonSAT

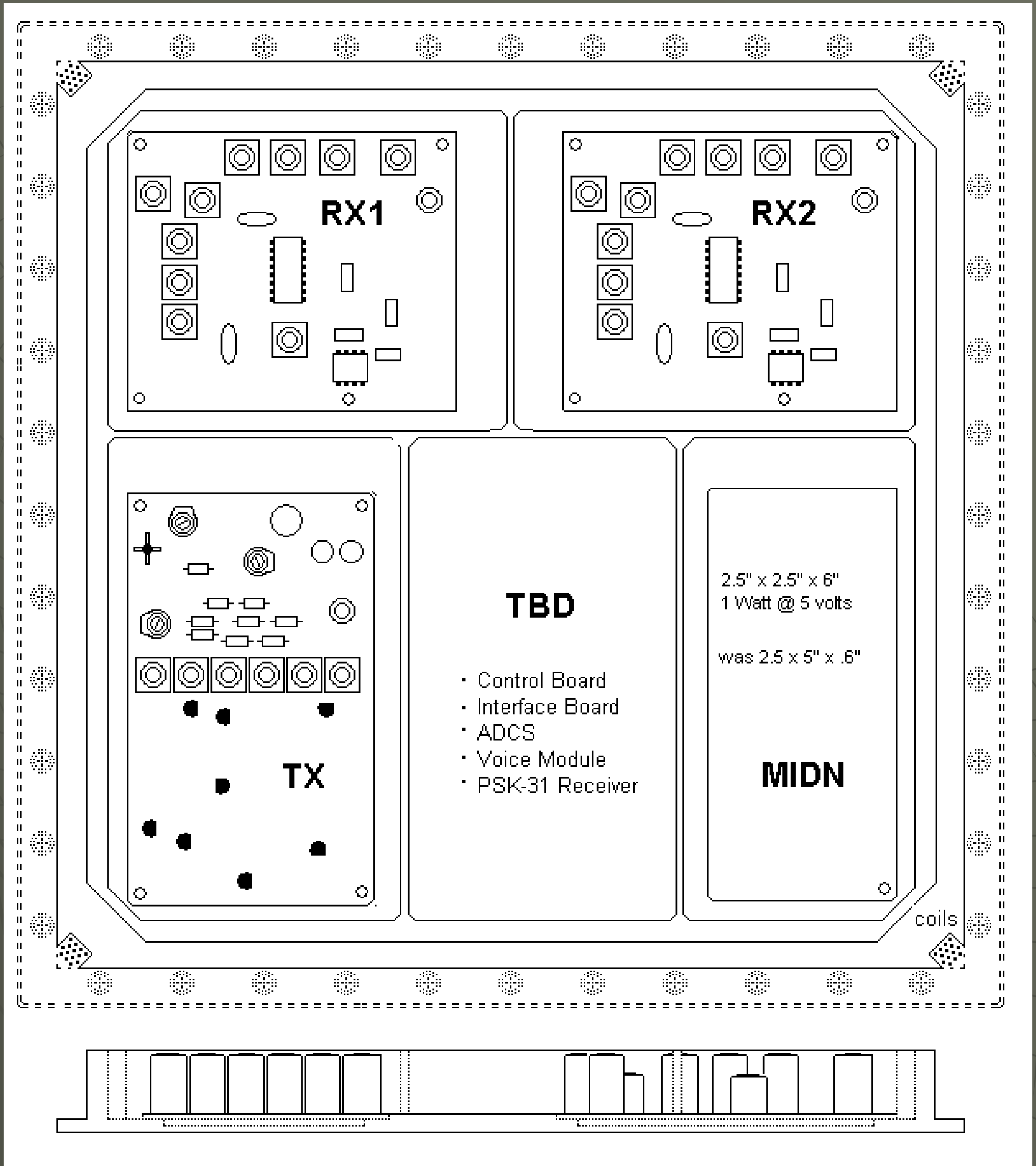
Internal Stack

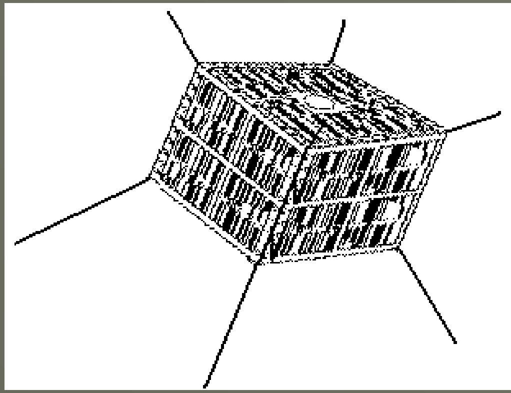




- Full capacity mission transponders
- ODTML Transponder
- MIDN Payload
- ADCS advantage

Vandegriff



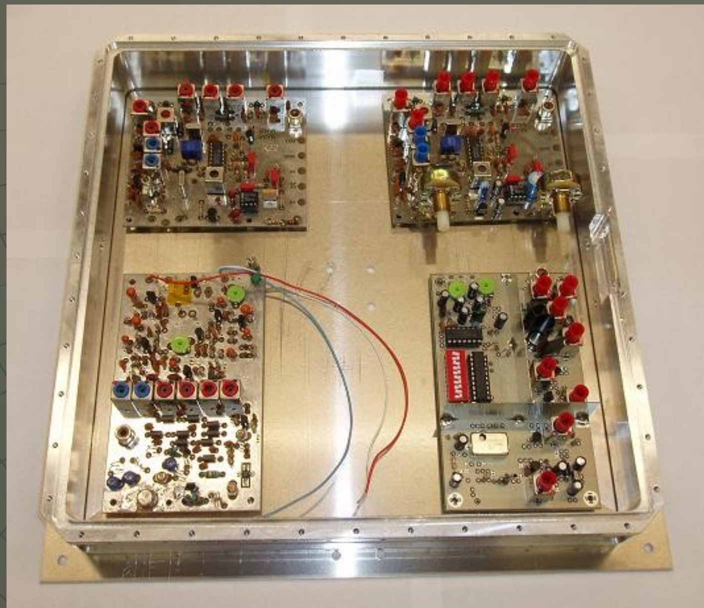


ParkinsonSAT
TX-RX Tray

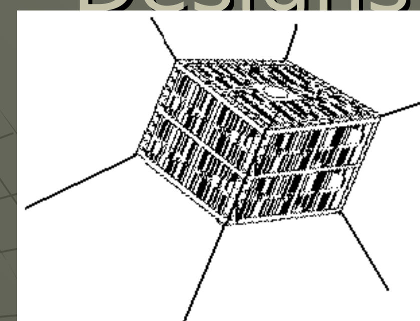
- 2 VHF receivers
- 1 or 2 XMTRS
- MIDN Payload
- Support Boards

Koeppel

Representative Tray Designs



TX-RX Tray



Layout favors +Z

maximum moment of inertia

TNC / Battery Tray

Koeppel

Preliminary Mass Budget

Part	Mass (g)	Quantity	Total (g)
Structure			
Side Panel	696	4	2787
PCSAT Solar Panel	77	25	1940
Top/Bottom Panel	796	2	1592
EMCOR Solar Panel	24	24	57
Mounting Tray	669	6	4015
Battery Box	354	1	354
Comms			
VHF RX	78	4	313
Linear RX	78	1	78
VHF TX	80	1	80
UHF TX	80	2	161

Vandegriff

Preliminary Mass Budget (cont)

Payloads	Mass (g)	Quantity	Total (g)
MiDn	529	1	529
ODTML Transponder	3700	1	3700
ADCS			
x-coil	127	1	127
y-coil	127	1	127
z-coil	110	1	110
CPU	62	1	62
Power			
Battery	23	36	856
Overall Total			17.3 kg

Preliminary Required Power Budget

4 RX / 2 TX	Curren t (mA)	Duty Cycle	Avg (mA)
VHF FM TX1	500	15%	75
VHF FM TX2	500	15%	75
VHF FM RX1	30	100%	30
VHF FM RX2	30	100%	30
VHF FM RX3	30	100%	30
VHF FM RX4	30	100%	30
TNC1	30	100%	40
TNC2	30	100%	40
W/o MiDn/ODTML			
20% Reserve	40		40
Avg (mA)			390

	Current (mA)	Duty Cycle	Avg (mA)
With MiDn only	119	100%	119
20% Reserve (tot)	64		64
Avg(mA)			533

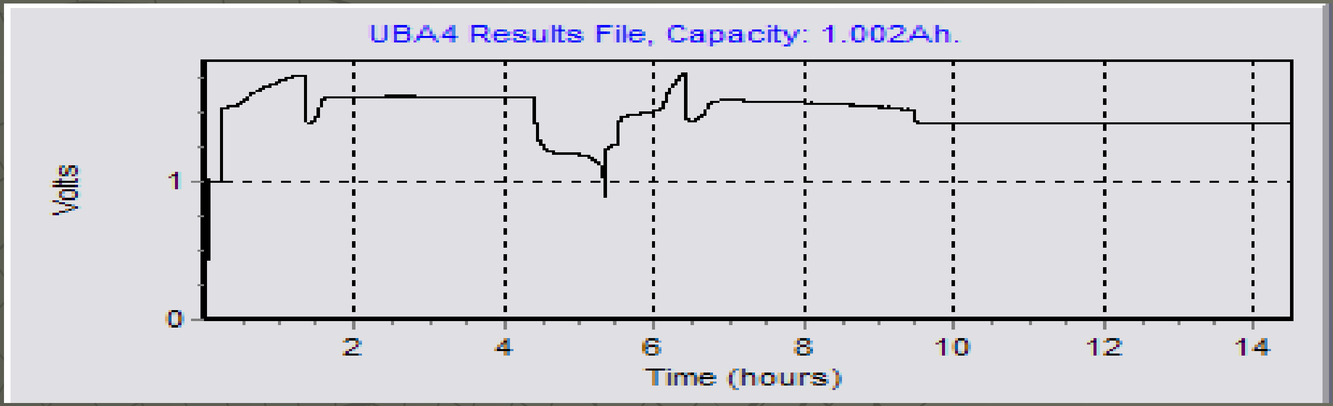
Minimum of 4.5W

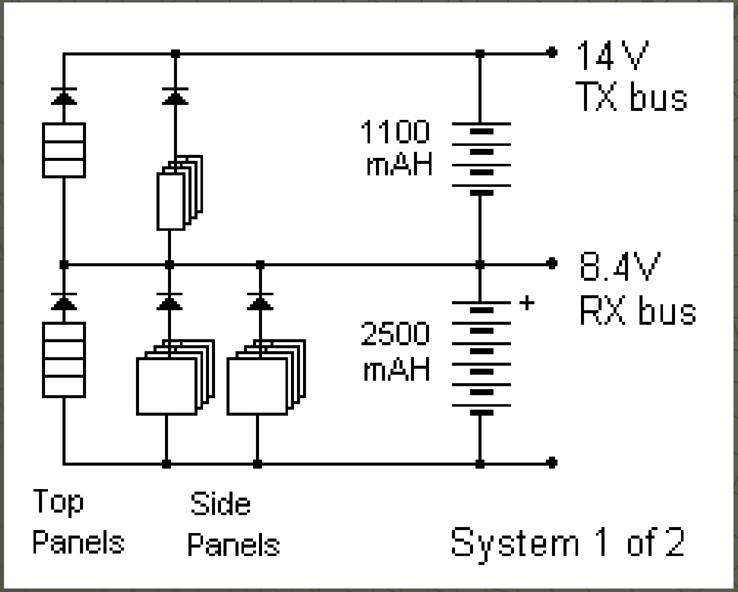
With MiDn and with	119	100%	119
ODTML transponder (10W)	1200	100%	1200
20% Reserve (tot)			361
Avg (mA)			2040

Maximum of 17 W

Vandegriff

ParkinsonSAT Battery Tests

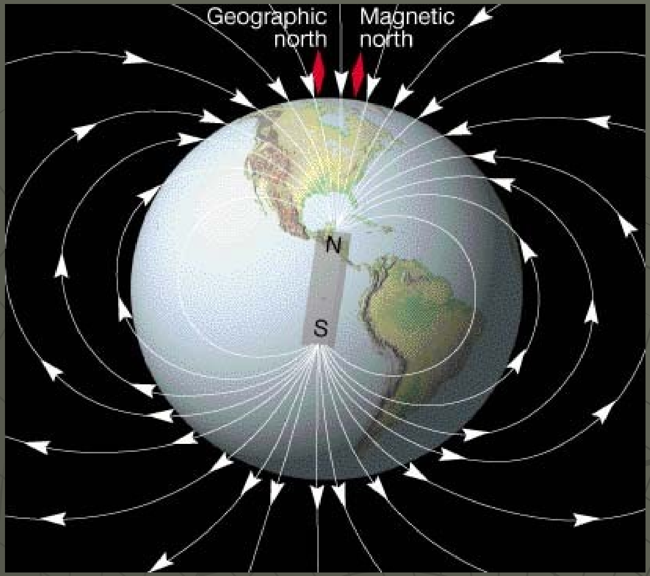




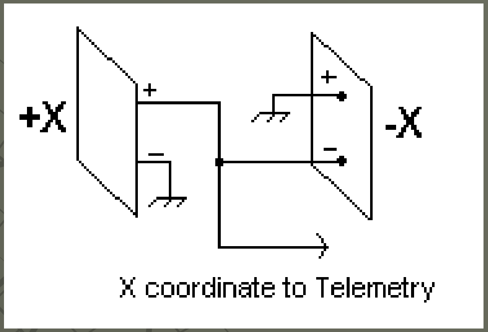
For a typical COMM orbit at 500 miles, satellite will require 630 mAh. Based on 20% DoD this requires either 27 AA's, 12 C's or 7 D cell NiCads.

Dual Voltage Bus for best efficiency / simplicity

Koeppel



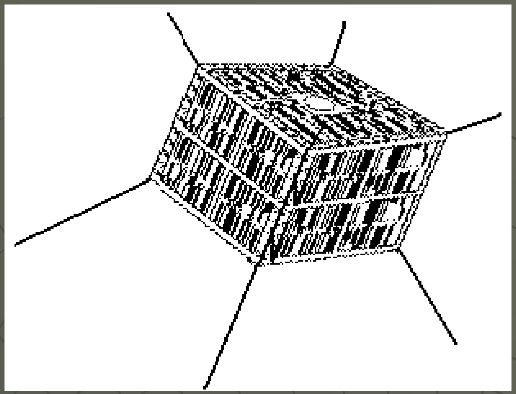
Sun Pointing Attitude Control System



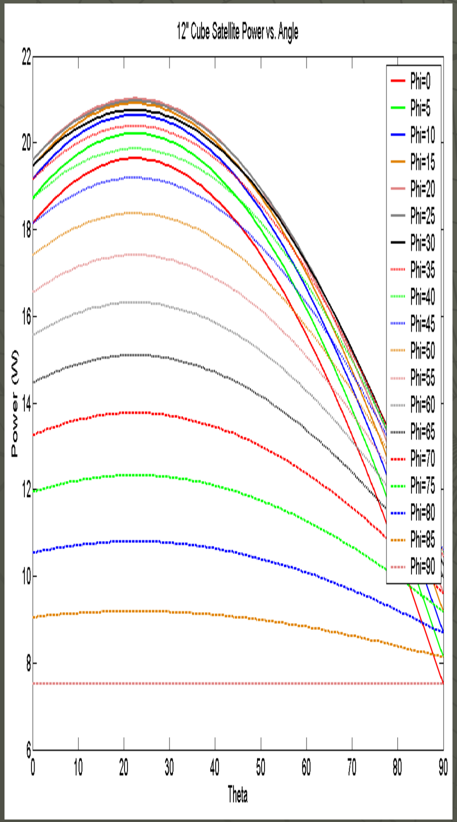
Attitude Vector

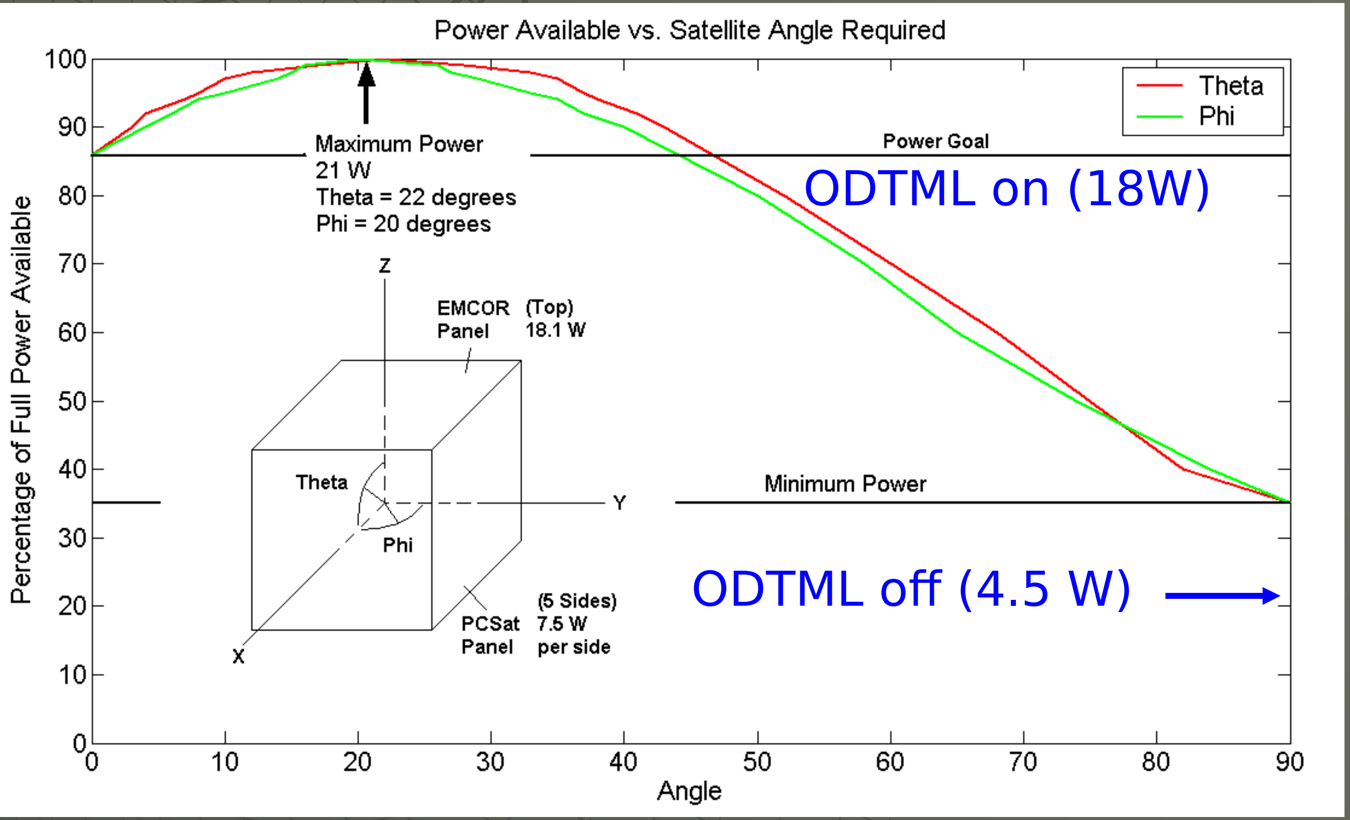
- ✓ Reduces solar panel cost, $54,000 to $9000.
- ✓ Pointing requirements are relaxed +/- 40 deg
- ✓ Attitude sensing will need simple magnetometer
- ✓ Table derived magnetic field data
- ✓ High precision vector math not required

Sun Pointing Attitude Control System



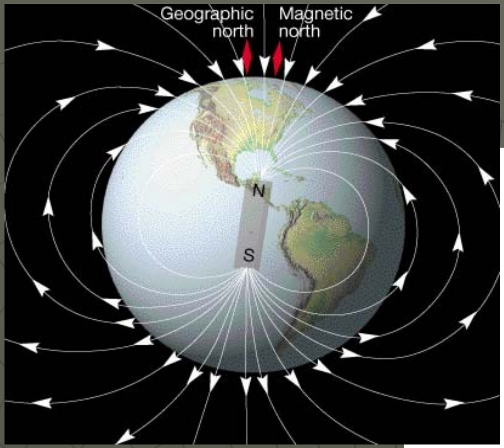
- ✓ Pointing requirements are relaxed +/- 40 deg
- ✓ High precision vector math not required

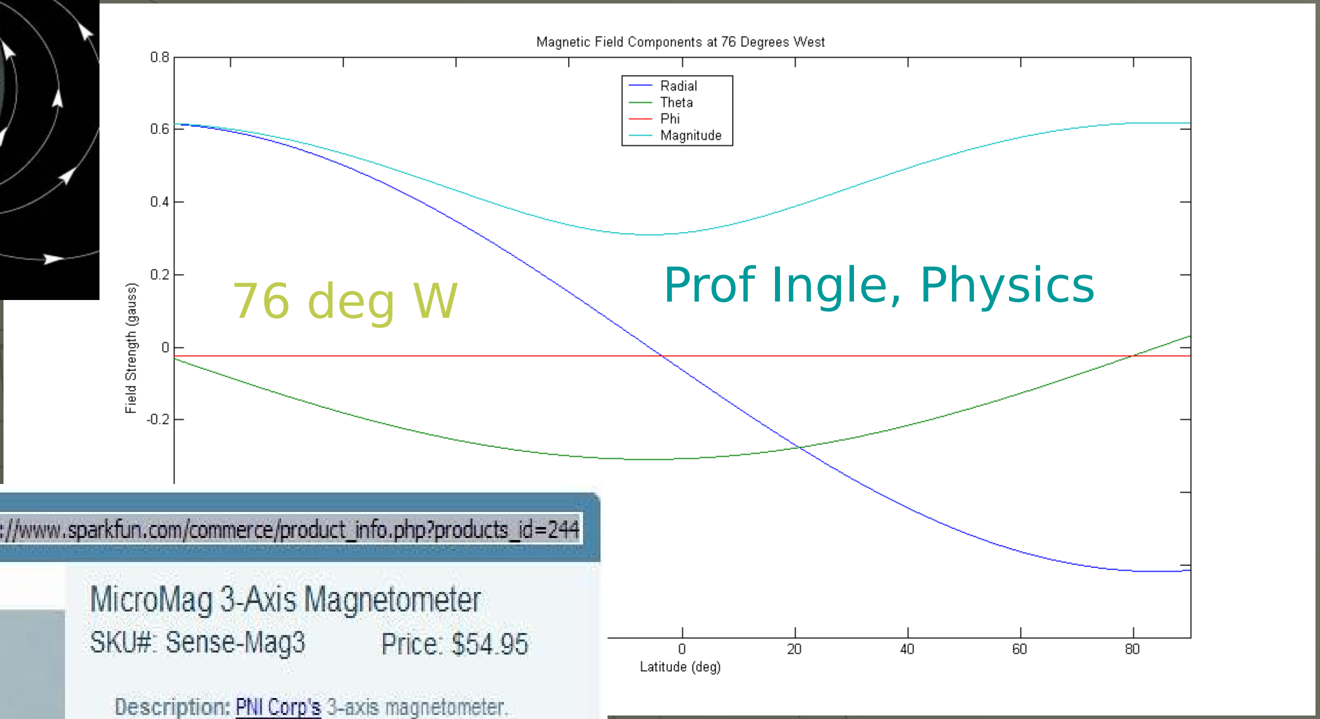




Paquette

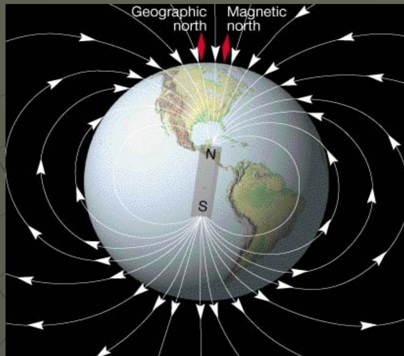
Magnetic Field Vector





76 deg W

Prof Ingle, Physics



Magnetic Torque Requirement

Worst Case Disturbance Torques:

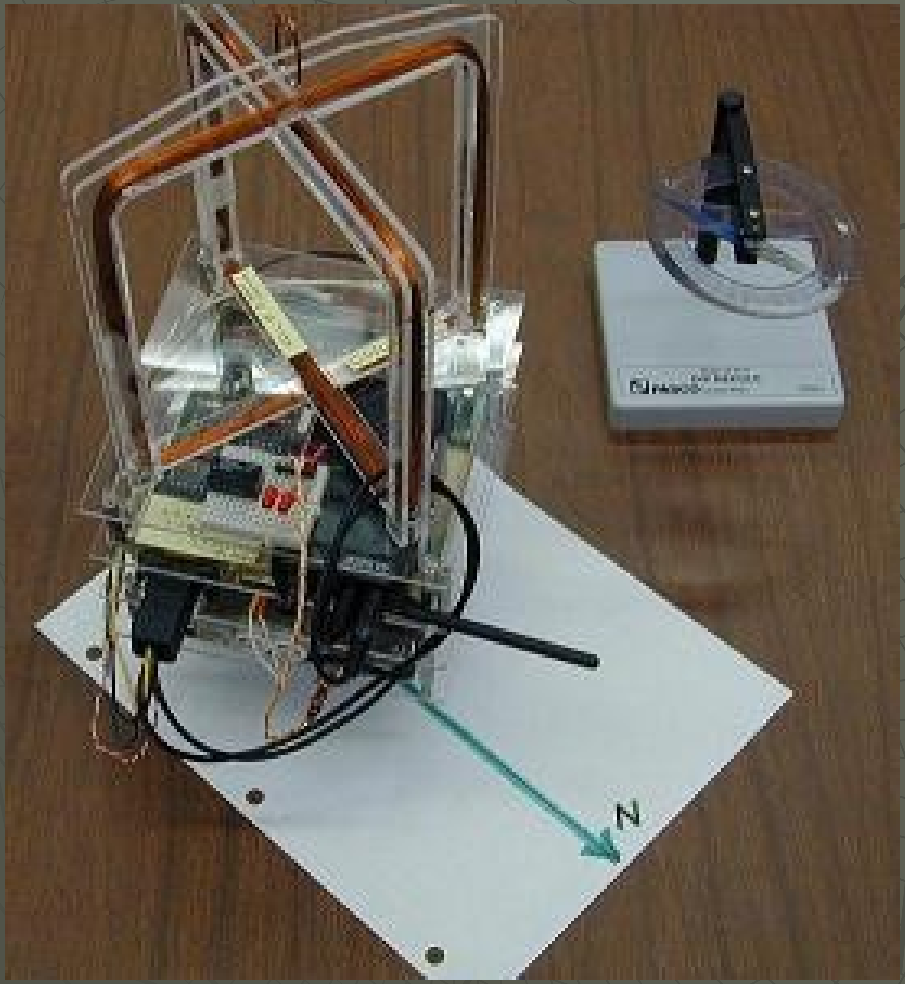
- Gravity Gradient (~balanced MOI from RAFT model)
  - $T_g=3*\mu/(2*r^3)*|I_z-I_y|*\sin(2*\theta)$ $T_g=6.30*10^{-25}$ N-m ≈ 0 N-m
- Solar Radiation
  - $T_{sp}=F*(C_{ps}-C_g)$ w/ $F=F_s/C*A_s*(1+q)*\cos(i)$ $T_{sp}=1.03*10^{-7}$ N-m
- Aerodynamic Drag (Assumed 500 km)
  - $T_a=1/2*\rho*C_D*A*V^2*(C_{pa}-C_g)$ $T_a=1.48*10^{-6}$ N-m
- Total Disturbance Torque
  - $T_d=1.58*10^{-6}$ N-m

Dipole Needed to Cancel Torques (weakest Earth field at 500 km):

- $D=T_d/B$ $B=0.31*10^{-4}$ T $D=0.051$ A m^2

Paquette

Magnetic Torque Coils



Torque Lab Experiment

- 200 turns #30
- 42 Ohms, 200 mA
- 1.3 Amp * M^2
- 1.4 kg
- Results in 5 deg / sec

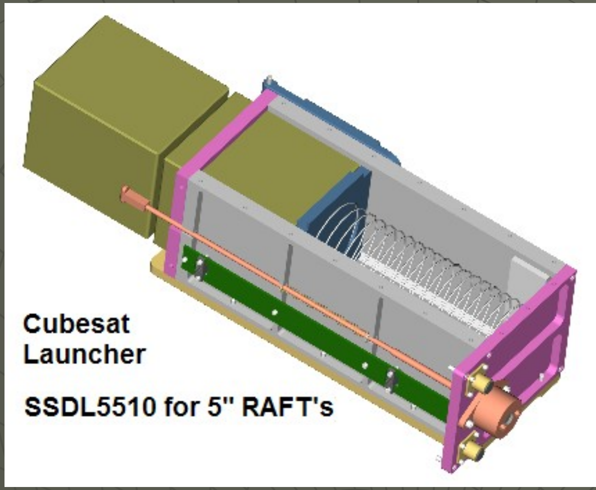
Suggests for ParkinsonSAT

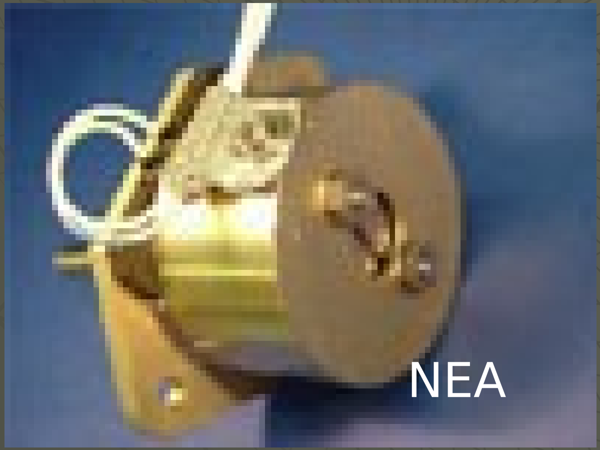
- 200 turns #30
- 4 Amp * M^2
- 14 kg
- Results in 1.5 deg / sec

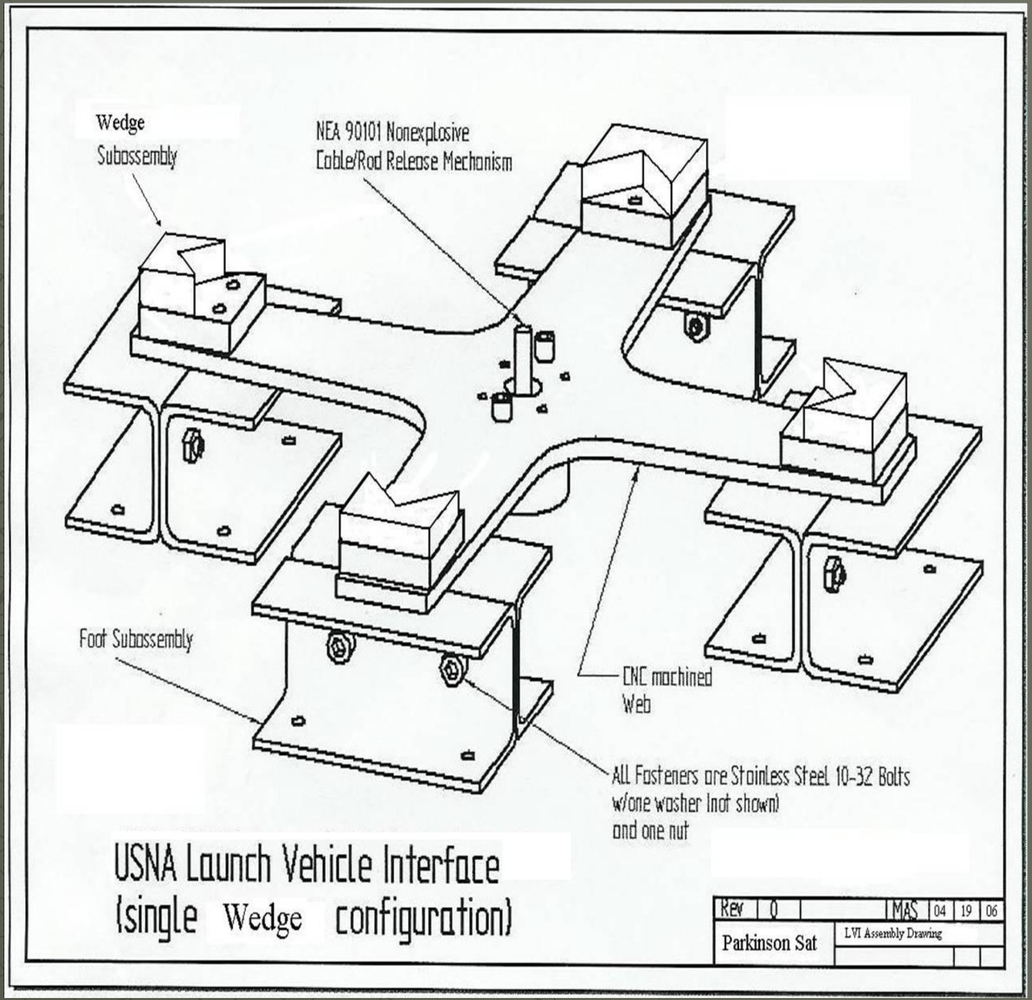
Using 10% dutycycle pulsing still gives 10 dB margin

Paquette

Launcher Separation Devices







Robeson

CPU Design

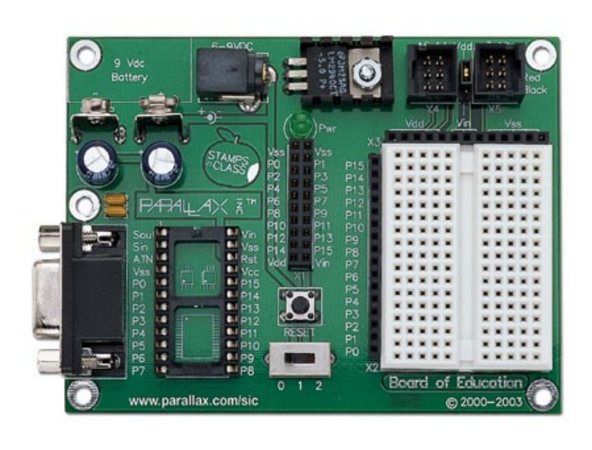
Adding CPU to basic PCSAT type design for:

- Collect and transmit whole orbit data telemetry
- Event scheduler
- Data logger
- Attitude control system
- Store and Forward

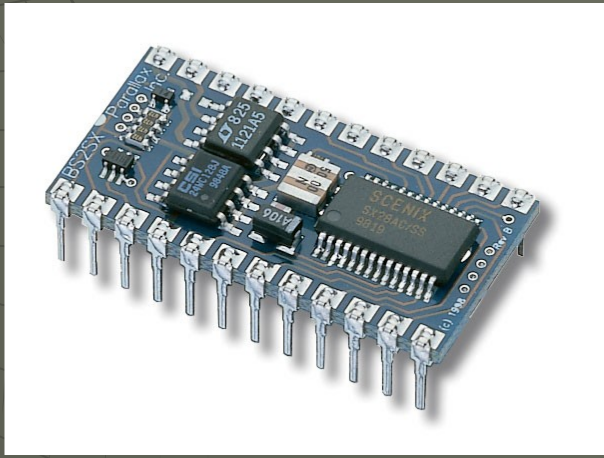
Includes…

-Serial port, 9600 or 1200 baud
-8-bit parallel I/O
-5 or more analog inputs

Development Board



CPU Module



Piggrem

Prototype Buoy Design

- Design aspects similar to spacecraft:
  - Power System (EPS) (low-power & efficiency)
  - Communications System (link budget)
  - Sensor system (collaborating with Oceanography)
  - Telemetry System
  - Antenna System (antenna patterns)
- Structure
  - Collaborating with Hydro Lab

Sensor Buoy Baseline

Naval Academy Student Project

* If free-floating, do not disturb.
* If aground, move to deep water
  and advise bruninga@usna.edu
* If later than 30 Nov 2006, recover
  and advise above.

See Buoy Location and Telemetry at

http://www.ew.unsa.edu/~bruninga/buoy.html

Piggrem

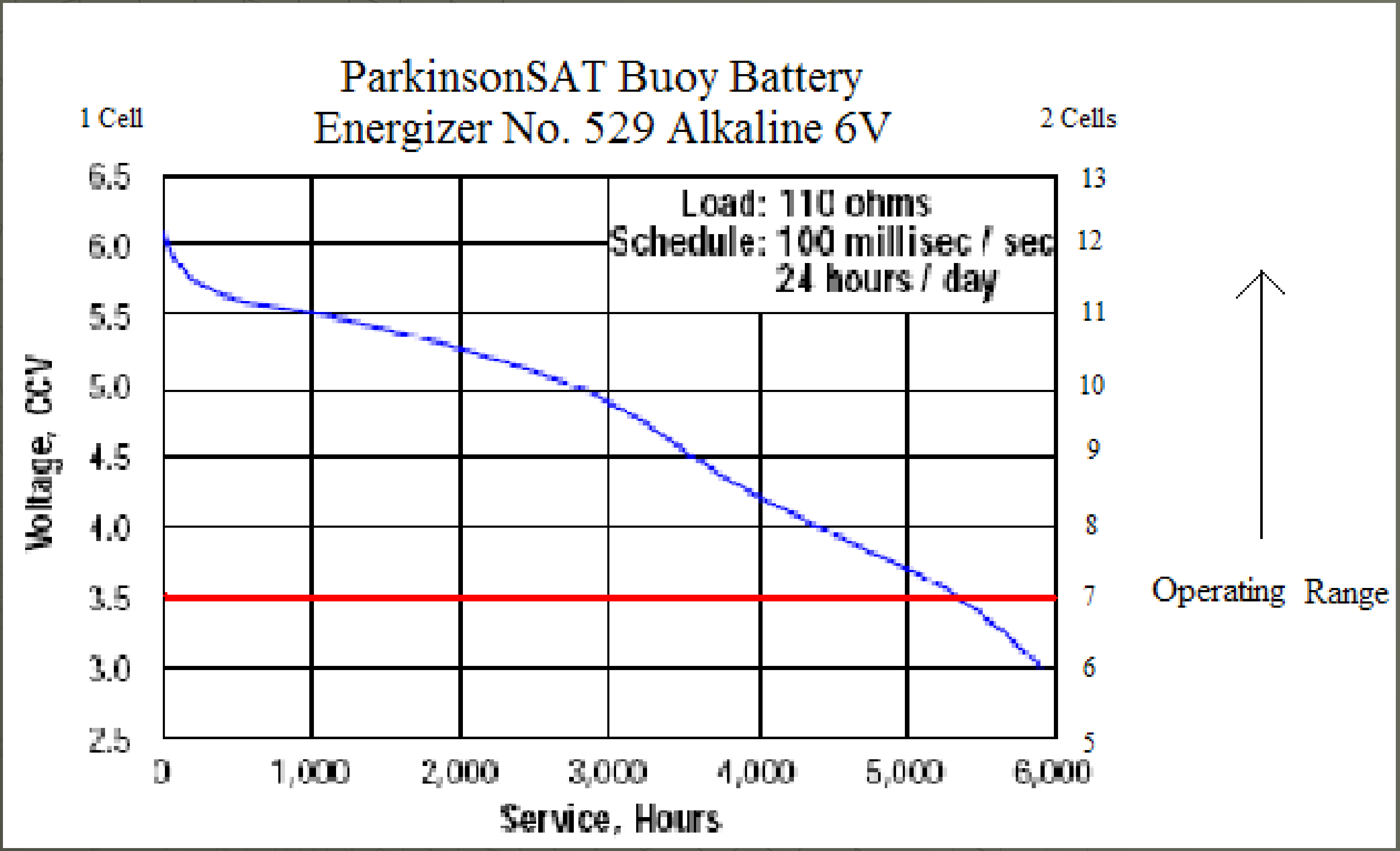
Buoy Power Budget

Energizer 6V Lantern Battery (No. 529)	Voltage (V)	Resistance (Ω)	Current (mA)	Time On (h)	Capacity (mAh/day)	Published Battery Capactity (Ah)	Battery Life (days)
	6	110	54.55	2.4	130.91	26	199
Component	Current (mA)	Time On (min/hr)	Required Energy (mAm/h)	Required Energy (mAh/Day)	Total Energy (mAh/Day)	Published Battery Capactity (Ah)	Battery Life (days)
Garmin GPS-18	110	2	220	88	128	26	203
Transmitter	500	0.2	100	40			

* 2 batteries required to get 12v BOL and 7v EOL

Piggrem, Koeppel

Buoy Power Budget



Piggrem, Koeppel

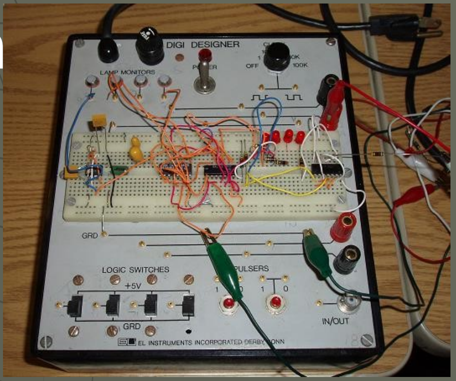
Buoy Logic Timing Design

Prescribed Timing Requirements for Bay Mission

- GPS – 1.4 minutes on every 23.4 minutes
- Transmits every 10 minutes
- TNC – 11 seconds on every 11 minutes

Prescribed Timing Requirements for Ocean Mission

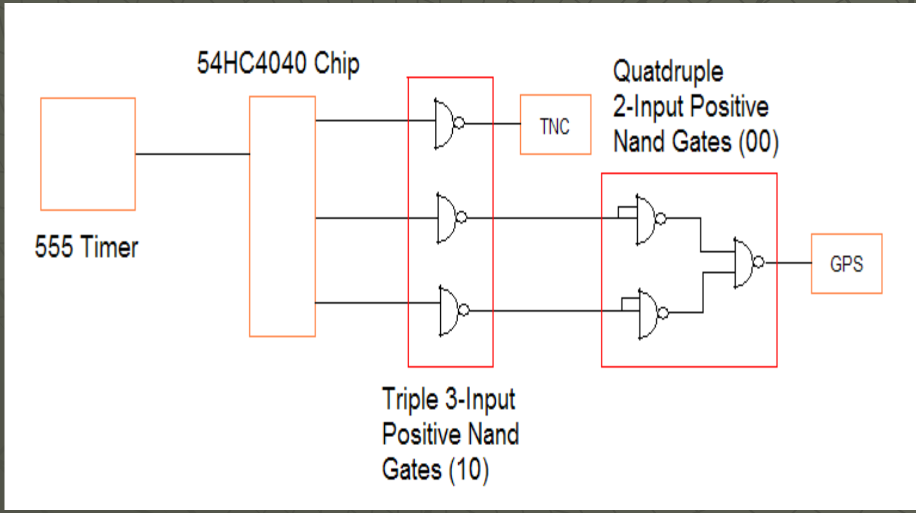
- TNC – 22 seconds on every 2.9 min
- GPS – 1.4 minutes every 46.9 minu
- Transmits every 2.9 minutes

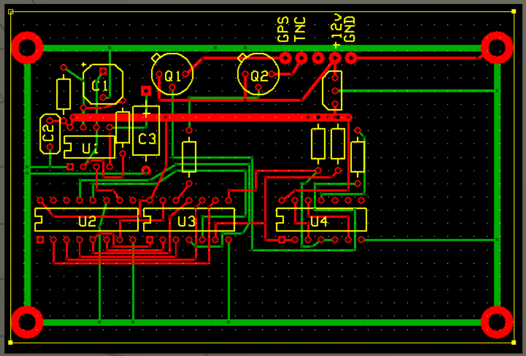


Lovick

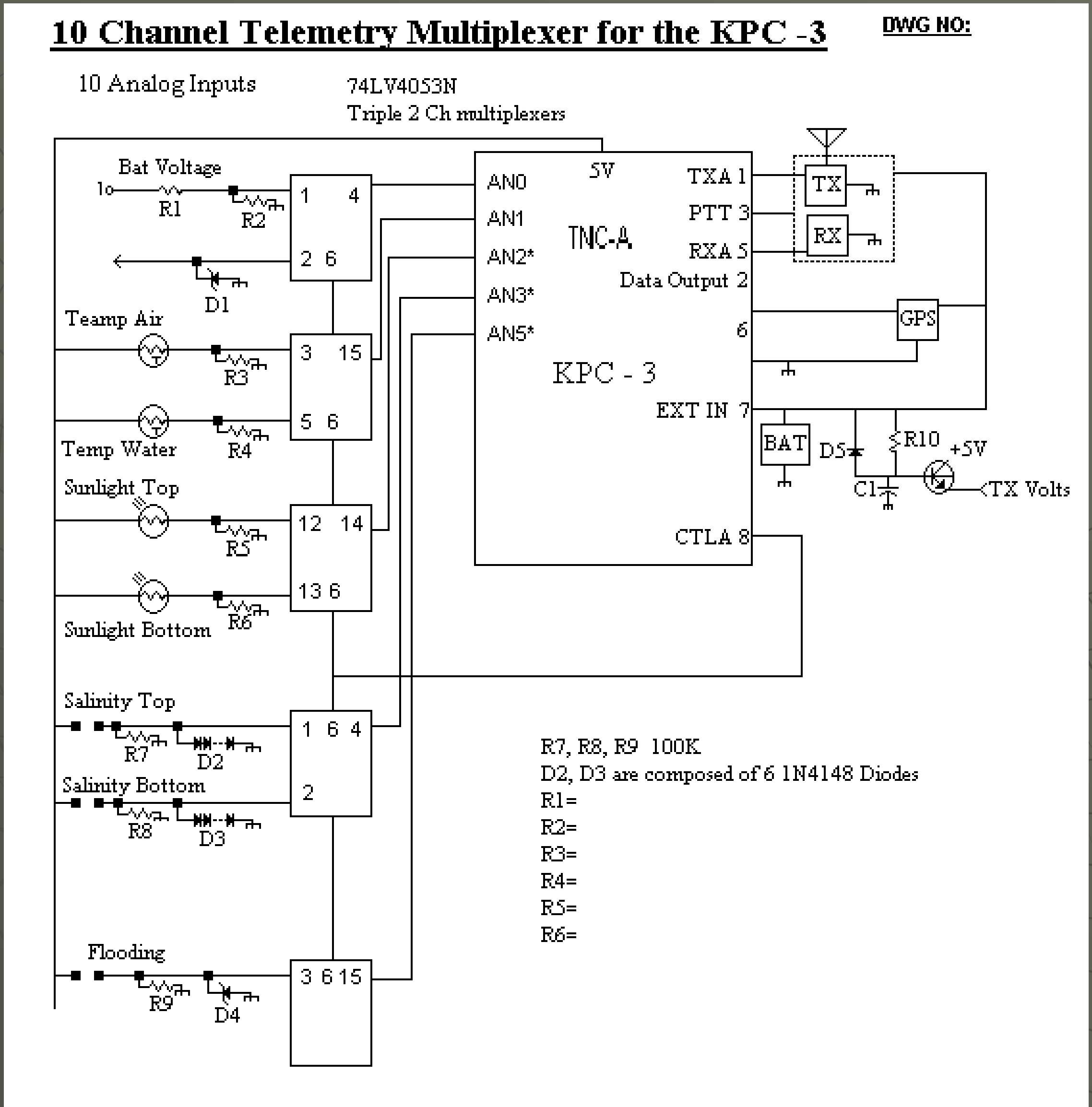
Buoy Logic Timing Hardware Integration

- Astable Operating 555 Timer (Clock Input)
- 54HC4040 12-Stage Binary Ripple Counter
- Triple 3-Input Positive Nand Gate Chip
- Quadruple 2-Input Positive Nand Gate Chip





Lovick

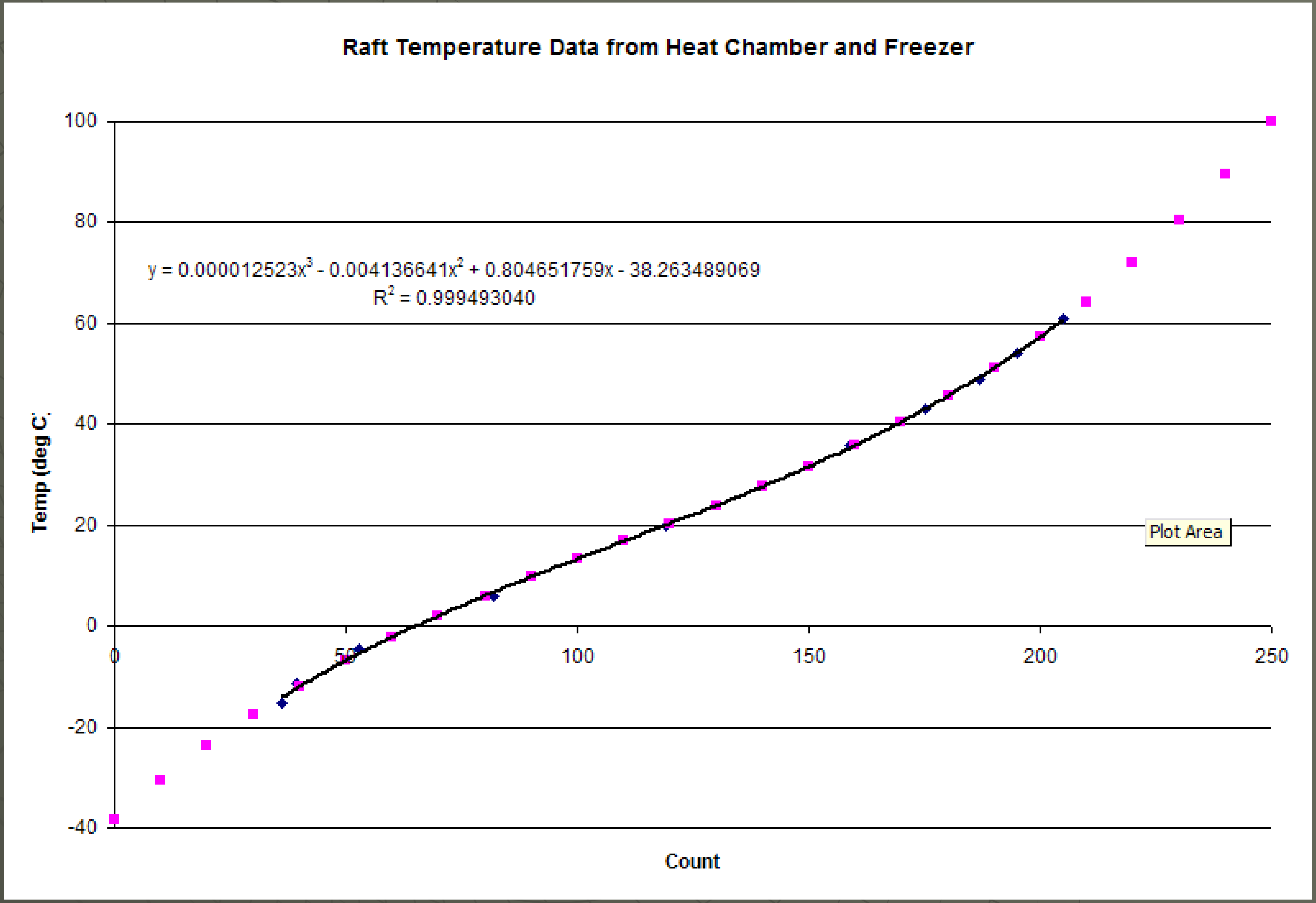


Buoy Telemetry

- Battery Volts
- Air Temp
- Water Temp
- Sun luminosity
- Conductivity
- Flooding

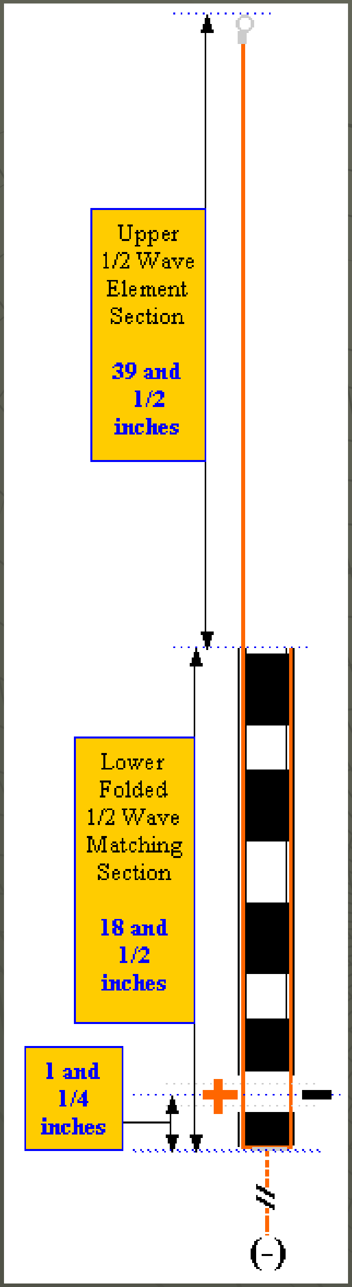
Paquette

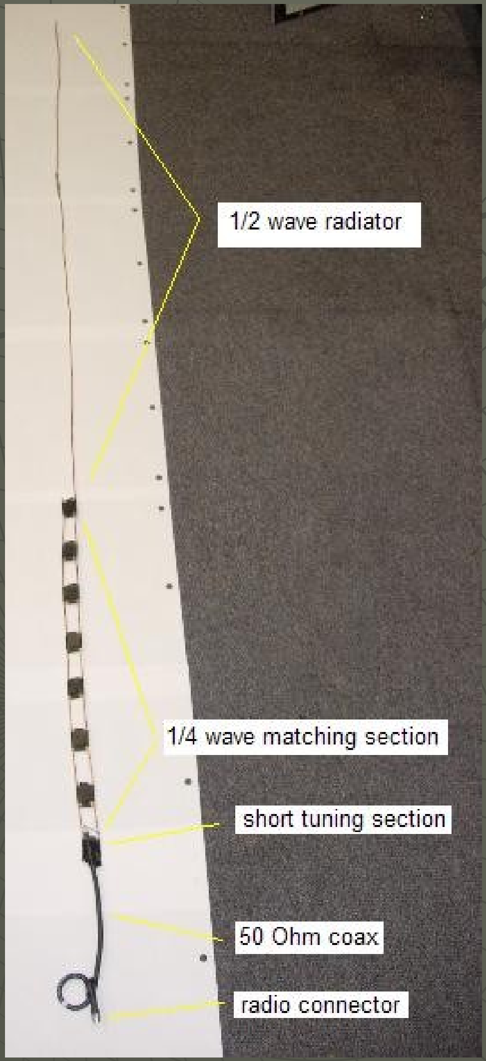
ParkinsonSAT Thermister Calibration Curve

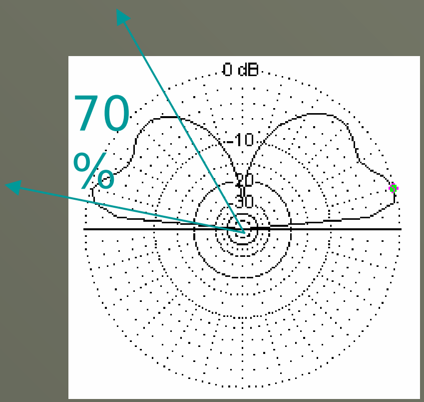


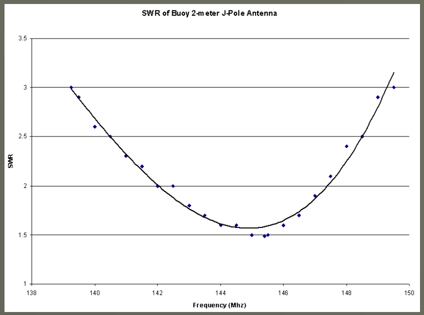
Paquette

Buoy Antenna Design



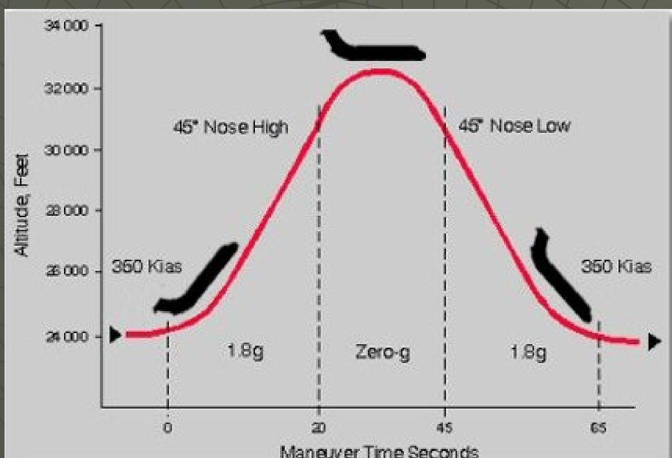






Paquette

ParkinsonSAT 5” Option microgravity Separation Test



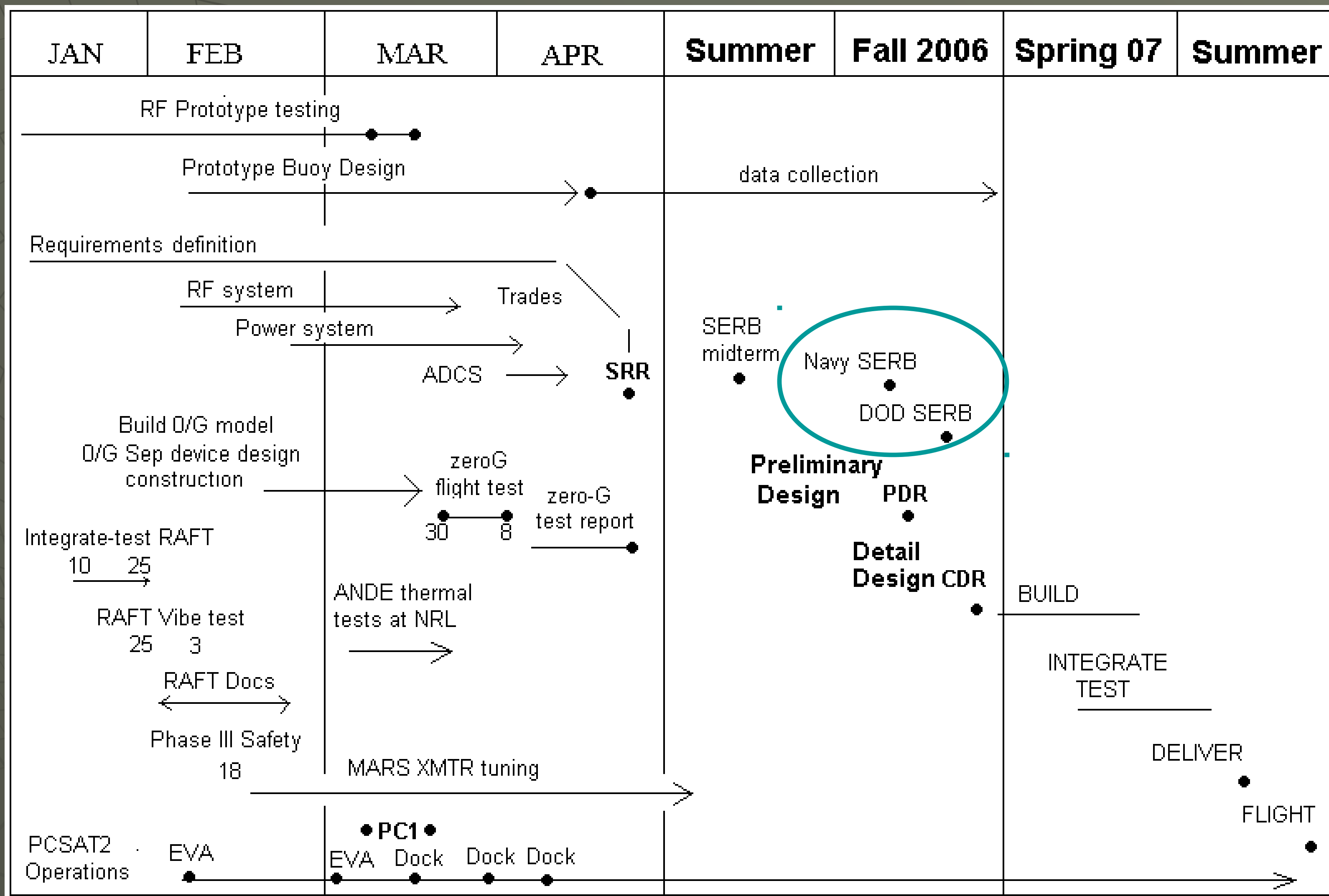
March 30th – April 8th

(“Test of Opportunity”)

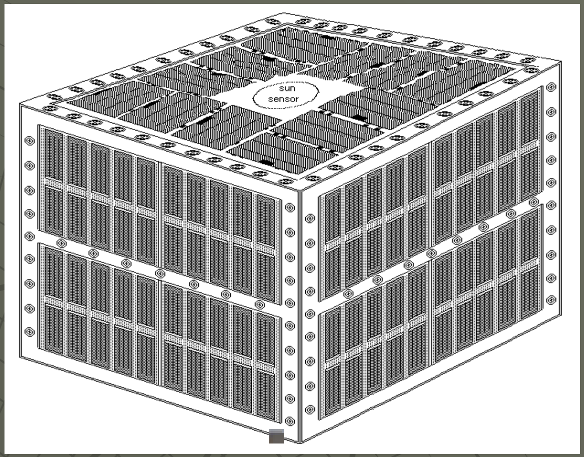
Robeson

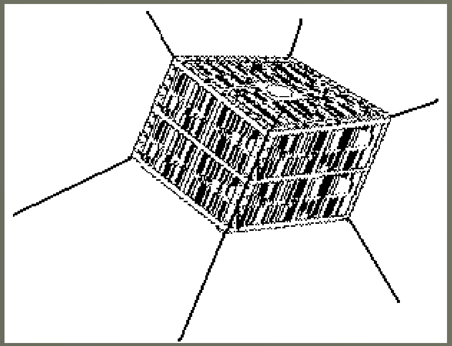
Test 5” cubesat separation system

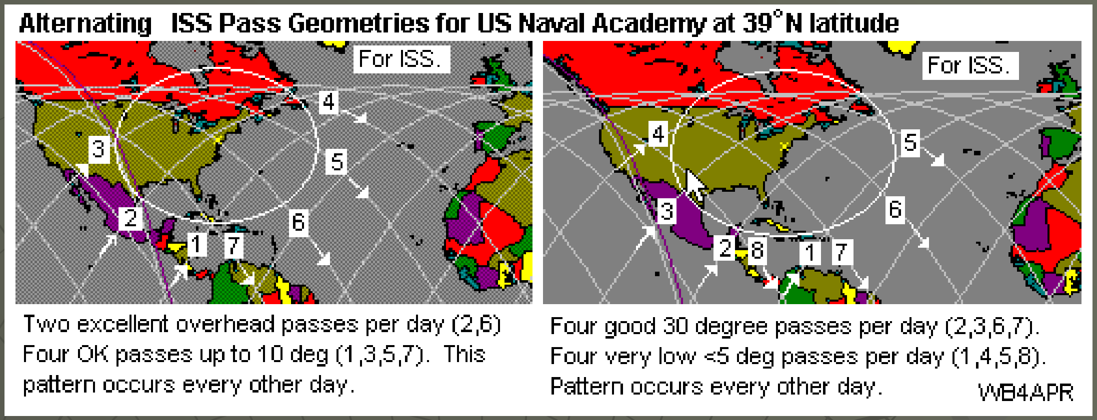
Robeson

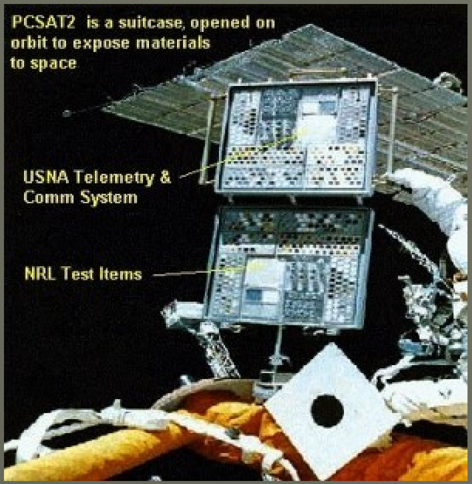

JAN
FEB
MAR
APR
Summer
Fall 2006
Spring 07
Summer
RF Prototype testing
Prototype Buoy Design
data collection
Requirements definition
RF system
Trades
Power system
ADCS
SRR
SERB midterm
Navy SERB
DOD SERB
Build 0/G model
0/G Sep device design
construction
zeroG flight test
30
8
zero-G test report
Preliminary Design
PDR
Integrate-test RAFT
10
25
Detail Design CDR
BUILD
ANDE thermal tests at NRL
RAFT Vibe test
25
3
INTEGRATE TEST
RAFT Docs
Phase III Safety
18
MARS XMTR tuning
DELIVER
FLIGHT
PCSAT2 Operations
EVA
PC1
EVA
Dock
Dock
Dock

Questions?









- PCSat2 Operations
  - Daily Antenna Pointing
  - Low Power Shutdown
  - Soyuz Docking
  - EVA's
    - SuitSAT deployment